VSB – Technical University of Ostrava

Faculty of Electrical Engineering and Computer Science

DIPLOMA THESIS

2019 **ANTON VINOTH SOUNDRARAJ**

VSB – Technical University of Ostrava

Faculty of Electrical Engineering and Computer Science

Department of Cybernetics and Biomedical Engineering

Control and Visualization for demo conveyor loop with different belts based on PLC

Řízení a vizualizace modelového dopravníku pomocí PLC

2019 **ANTON VINOTH SOUNDRARAJ**

VŠB - Technical University of Ostrava
Faculty of Electrical Engineering and Computer Science
Department of Cybernetics and Biomedical Engineering

Diploma Thesis Assignment

Student: **Anton Vinoth Soundraraj**

Study Programme: N2649 Electrical Engineering

Study Branch: 2612T041 Control and Information Systems

Title: Control and Visualization for Demo Conveyor Loop with Different Belts based on PLC
Řízení a vizualizace modelového dopravníku pomocí PLC

The thesis language: English

Description:

A conveyor loop is used for demonstrating transport tires on different belts on conveyors. These conveyor are installed in loop with one in-feed and one out-feed conveyor. In this loop, different belts standard conveyors are used and two conveyors are special with local logic card for non touch function.
The objective of the thesis is design of controls using PLC, HMI and industry standards accessorizes.

Points of entry:
1. Introduction to the technology.
2. Functional analysis of the controlled system.
3. Design of a control system concept.
4. Design and implementation of a control application for PLC.
5. Design and implementation of a control application for HMI.
6. Verification of designed function on conveyors loop.
7. Evaluation of the results of work solutions.

References:

[1] BERGER, Hans. *Automating with SIMATIC.* 5th edition. Erlangen, Germany: Publicis Publishing, 2013, 284 p. ISBN 978-3895783876.
[2] BERGER, Hans. *Automating with SIMATIC S7-1500: Configuring, Programming and Testing with STEP 7 Professional.* Hardcover, 2014. ISBN 978-3895784040.
[3] Technical documentation for Simatic.

Extent and terms of a thesis are specified in directions for its elaboration that are opened to the public on the web sites of the faculty.

Supervisor: **doc. Ing. Jiří Koziorek, Ph.D.**

Date of issue: 01.09.2018

Date of submission: 30.04.2019

doc. Ing. Jiří Koziorek, Ph.D.
Head of Department

prof. Ing. Pavel Brandštetter, CSc.
Dean

Declaration made by Student:

"I hereby declare that this master's thesis was written by myself. I have quoted all the references I have drawn upon"

Anton Vinoth Soundraraj

Declaration made by the cooperating legal or natural person:

"I hereby agree to the publishing of the master's thesis as per s. 26 ss. 9 of the study and examination Regulations for Master's Degree Program at VSB-Technical University of Ostrava

Anton Vinoth Soundraraj

Abstract

The main objective of this project is to control a demo conveyor loop with different belts using Programmable logic controller (PLC), HMI and integration of non-touch accumulation zones in industry standard accessories. This project is used for transporting passenger car tires on different belts of conveyors. These conveyors have been installed in loop as one in-feed conveyor and one out-feed conveyor. The key points of entry in this project are functional analysis of the controlled system, designation of the control system concept, design and implementation of a control application for Programmable Logic Controller (PLC), design and implementation of the control application for Human Machine Interface (HMI), Verification of designed functions on the conveyors loop and to evaluate the results of the work solutions.

Abstraktní

Hlavním cílem tohoto projektu je řízení demo dopravníkové smyčky s různými řemeny pomocí programovatelné logiky Controller (PLC), HMI a integrace Non-touch akumulační zóny v průmyslovém standardu příslušenství. Tento projekt slouží k přepravě pneumatik pro osobní automobily na různých pásech dopravníků. Tyto dopravníky byly instalovány ve smyčce jako jeden přívodový dopravník a jeden výtlačný dopravník. Klíčovými vstupními body tohoto projektu jsou Funkční analýza řízeného systému, označení koncepce řídicího systému, návrh a implementace řídicí aplikace pro programovatelný logický automat (PLC), návrh a implementace řídicí aplikace pro rozhraní Human Machine Interface (HMI), Ověření navržených funkcí na smyčce dopravníků a vyhodnocení výsledků řešení prací.

Table of Content

List of abbreviations used

AC	Analog Current
AS-I	Actuation Sensor Interface
CM	Communication Module
CPU	Central Processing Unit
DB	Data Blocks
DC	Direct Current
FC	Functions
FB	Function Blocks
FG	Flush Grid
HMI	Human Machine Interface
IO	Input Output
IP	Internet Protocol
IR	Insert Rollers
LED	Light Emitting Diode
LAD	Ladder Builder
FBD	Functional Block Diagram
MAC	Media Access Control
OB	Organisational Block
OP	Operating Panel
PC	Personal Computer
PEC	Photo Electric Cell
PLC	Programmable Logic Controller
PROFIBUS	Process Field Bus
PROFINET	Profibus on Ethernet
SCADA	Supervisory Control and Data Acquisition

SCL	Structured Control Language
SFT	Square Friction Top
SIMATIC	Siemens Automatic
STEP 7	Siemens Technical Education Program
TIA	Total Integrated Automation
TFT	Thin Film Transistor
TP	Touch Panel
TRT	Transverse Roller Top
WinCC	Windows Control Centre

List of Figure

List of Table

Introduction

The idea is to show the most relevant Intralox solutions for a tire industry. Lot of tire industries has been facing some issues like tire jam in transporting of tires in conveyor system because of friction of tires with the conveyor belts and body; sometimes it would cause scrapings of tires. These issues are because of transporting tires on conveyor which are not suitable or flexible for the outer body of the tires. Here we are introducing special roller system on the conveyor belts which will make the transportation of tires away from jams and scraps. This system is basically a test loop for passenger car tires with different kinds of belt with width of 913 mm which is suitable for whole range of passenger car tires and the nominal product speed of 30 meter/minute.

This system has an in-feed conveyor and gravity roller for out-feed. It has two S4400 TRT types of conveyors to make 180° transfer (one at the left side next to in-feed conveyor and one at the right side before the out-feed conveyor). Between these two conveyors, there is a four-meter energy reduction conveyor and also this 4 one-meter long accumulation zone belts. The paddle diverter sorts out the tires to the accumulation zone from S4400 TRT conveyor which is at the right side. The tires which are not sorted out by the paddle diverter will go straight on to the out-feed which has a gravity roller with a stopper. The tire from the gravity rollers can be manually put back into the loop via the in-feed incline conveyor. If there is already a tire on the outfeed conveyor, the paddle diverter diverts the tires from upstream on to the accumulation zone and it will be merged on to the infeed if there is not tire from infeed.

All the conveyors are driven by SEW EURODRIVE MOVIMAT. This system has been controlled by using Siemens Programmable Logic Controller (PLC) S7-1200 which has the capacity to read 1000 instructions in 0.04 milli second. The PLC has been programmed by TIA PORTAL in Ladder Logic programming using different blocks and there is a Human Machine Interface (HMI) Operating panel KTP 700 Basic for visualization/monitoring of the system. All the devices are connected through AS-I master gateway to PLC as slaves. The communication between the PLC and the HMI are been done by using PROFINET.

1. Description of the controlled technology

1.1 Project Overview

What is Intralox solution?

It is a total transportation solution for maximum economic values in tire industries. Experience of product jams in the transportation, scrap from tires, and dealing with high maintenance and roller switches. The tire manufacturing industries have been to Intralox for assistance replacing tire sorter, one tire merger and tire transfer. The solution of the system is focusing on some processes like green tire handling, mixing and mill room, component preparation, tire building, curing and final finish areas.

Conveyors

One meter of S900 SFT incline conveyor has been used for in-feed and the out-feed has gravity roller with a stopper. One S4400 TRT conveyor has a static diverter arm with rollers, whereas the other S4400 TRT conveyor has a paddle diverter. Between these two S4400 TRT conveyors, it has a S900 IR energy reduction conveyor in the one side and on the other side it has two S900 IR PP belt and two S900 FG PP belt. The length of the S4400 TRT conveyor can be possible to replace in future with two S4500 DARB conveyors (no-touch merge and sort) or two S400 ARB 45 conveyors.

Controller

The system is controlled by using Siemens S7-1200 PLC. The PLC has been programmed by using Siemens Step 7 Tia PORTAL version 14 in ladder builder language.

Operating Panel

The system has an operating panel KTP 700 for visualization and monitoring of the system.

Communication

The communication protocols which are used here are ASI master/slave, profinet, hard-wire communication with Itoh Denki controller cards.

1.2 Intralox Solutions

Intralox Company has been providing complete transportation solutions for tire industries all over the world based on economic values. It has created notable economical value for the entire system, from in-feed to final finish level. Tire manufacturers all over the world have started saving their financial investment on their transportation lines by changing their system to an Intralox solution system. By using Intralox Transverse Roller Top (TRT) solutions, transfer of tires on a flat belt became unforeseen due to the friction between the tires and the rubber belt which will often result in jam of tires which has to be solve. Intralox solution also eliminates time wastage due to the jams of tires, therefore it reduces the need of manual handling. Based on this installation all over the world, customers receive repay of investment from the reduction of scrap tires within the installation period.

1.3 Intralox Processes

There are few processes in Intralox solutions which will lead the system to provide a solution form maximum economical value of total transportation. This gives a powerful processing effect and great return of economic value.

1.3.1 Mixing and millroom

This process is used to improve the efficiency and to reduce the downtime. There are five important benefits in this mixing and millroom process.

- It minimizes the repairing of belt
- It freezes out the slippage of belt and mistracing of belt from the roller shaft
- It reduces the sticking of rubber in the roller shaft and decreases the rubber jam
- It eliminates the damage which will cause at the edge of the belts
- It reduces the efficiency of rubber contamination.

1.3.2 Component Preparation

Twenty-five years ago, Intralox started their work on tire companies all over the world by installing side wall cooling line. But today, Intralox also providing transportation solutions in the component preparation area like feeders, takeaway etc. Intralox has been creating more consistence and methodical equipment in the department of component preparation.

1.3.3 Curing

Most of the times in tire industries, tire jams are happening in the trench conveyor lines of the system. This is because of without any support at the end of turning to the trench conveyors. It causes the delay and it affects the fluency of the system. In this case we are using Intralox transverse roller top (TRT) to completely reduce the tire jam which is happening in the trench conveyors. With this solution, tire manufacturer can calculate the time taken of the tire from one conveyor to the trench conveyor. It becomes unpredictable when you use normal flat bet for transportation, because of the friction of tires with the belt. This friction will lead the system to tires scraps, cost downtime etc.

1.3.4 Final Finish

Final finishing improving the regulation in the area of sorting of tires by using curves in the final finish areas. This makes the sorting, merging of tires and the transportation reliable. Usually the final finish area would be problematic and obviously it would need high maintenance. By using Transverse Roller Top Belt (TRT), we can make a system with no-downtime and no-maintenance. The 90 degree turn in the tire plant gets good improvement in time consumption. By using this system, the maintenance requirement has been got to low as possible. The Transverse Roller Top (TRT) belt on final finishing

areas like turning, sorting and merging processes is been effective. Most of the tire companies all over the world are using final finishing process in their system.

Reference: *http://www.intralox.com/*

1.4 Conveyor Loop and the Accumulation zone

In the below figure, you can clearly observe the system and also you can partially understand the working of the system.

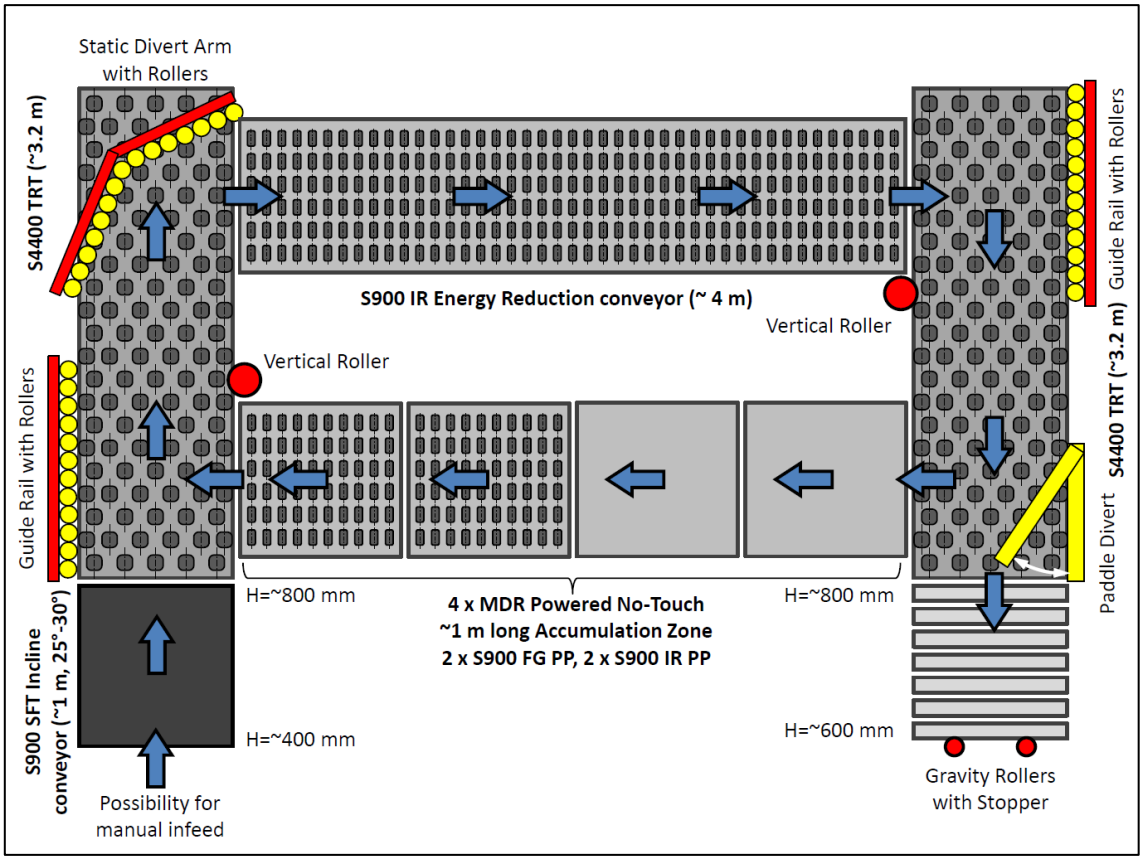


Figure 1. 1 *Layout of the System*

1.4.1 Apparatus

In this system we have different types of apparatus which will reduce the friction of tire with the sides of the conveyors. In this case, we are reducing the scraping of tires (from damage). The apparatus which are present here are;

i. Guide rail with roller (2)
ii. Static diverter arm with rollers (1)
iii. Paddle Diverter (1)

iv. Vertical Roller (1)

Guide rail with roller

There are two guide rails with rollers. One is fixed at the left side S4400 TRT conveyor (next to in-feed) and the other one is fixed at the right side of S4400 TRT conveyor. These two-guide rail with roller conveyors are used for making the 90 degree turn from accumulation zone to the left side S4400 TRT conveyor and from the energy reduction conveyor S900 IR to the right side S4400 TRT conveyor without causing any damage to the tires.

Static diverter arm with rollers

The static diverter Arm with rollers is present in the left side S4400 TRT conveyor. These rollers will rotate in clockwise direction which would lead the tire to the S900 IR Energy Reduction Conveyor (ERC). These rollers prevent the tires from scratching in the conveyor corners.

Paddle Diverter

We have a paddle diverter just before the out-feed (gravity roller with stopper). This paddle diverter will divert the tire from right side S4400 TRT conveyor to the accumulation zone when there is already a tire on the out-feed gravity roller.

Vertical Roller

There are two vertical rollers. One is between the accumulation zone and the left S4400 TRT and the other one is between the right side S4400 TRT and the S900 IR energy reduction conveyor. These vertical rollers are fixed for reduction of tire friction when 90 degree turn from accumulation zone to the left side S4400 TRT conveyor and the 90 degree turn from S900 IR energy reduction conveyor to the right side S4400 TRT conveyor.

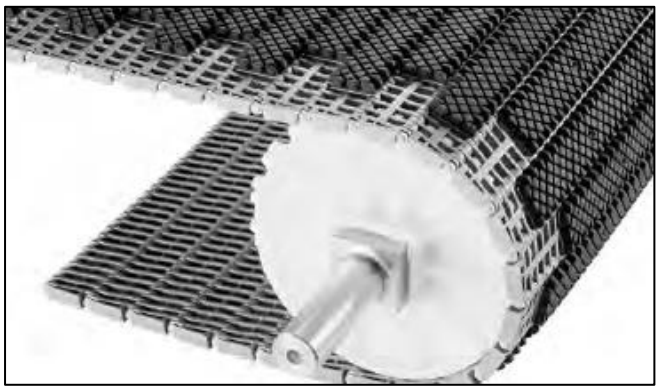
1.4.2 Conveyors

Here we are using different types of belt. Such as

i. S4400 TRT conveyor (2)
ii. S900 SFT conveyor (1)
iii. S900 IR Energy reduction conveyor (1)
iv. S900 FG (2)
v. S900 IR (2)
vi. Gravity roller with stopper (1)

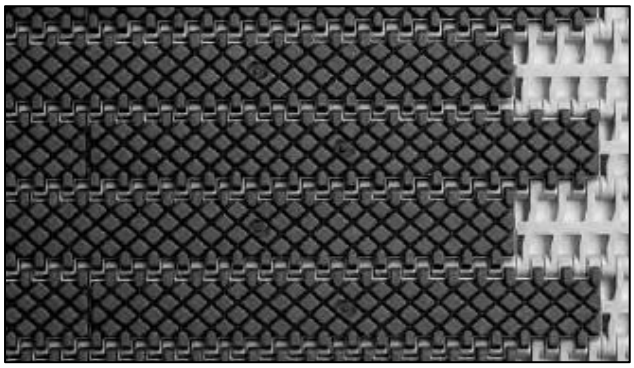
S900 SFT Conveyor

SFT means Square Friction Top. It is the infeed conveyor. It has a high friction surface made up of rubber which will grip the tyre. It does not have any connection with sprocket.



[9]

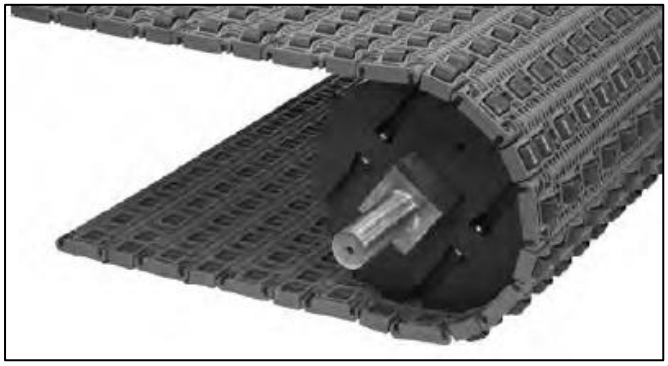
Figure 1. 2 *S900 SFT with roller Shaft*



[9]

Figure 1. 3 *S900 SFT top view*

S4400 TRT Conveyor



[9]

Figure 1. 4 *S4400 with roller Shaft*

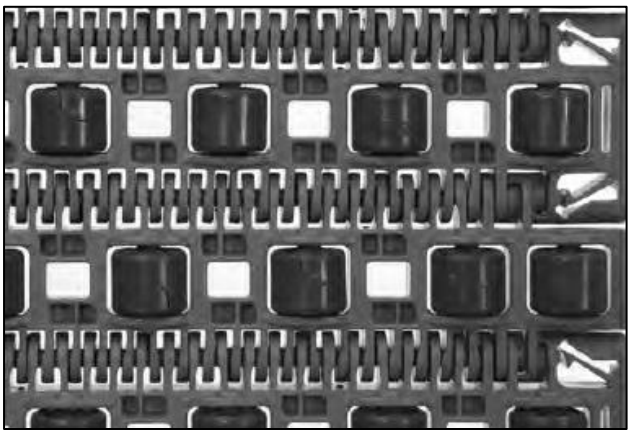

[9]

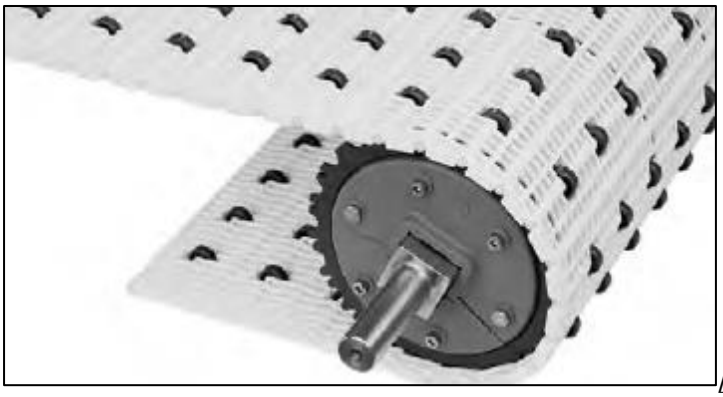
Figure 1. 5 *S4400 top view*

There are two S4400 TRT conveyors are present in this system. The pitch of these belt is 50.8 mm, the minimum width of the belt is 203 mm and we can increase the width to extra 50.8mm. Belt consists of plastic axles in the form of acetal roles which is designed for 90-degree transfer. The diameter of the roller is 24.1 mm and the length of the roller is 20.9 mm. robust design offers excellent belt and sprocket durability, especially in tough, material-handling applications. The sprockets have large lug teeth. S4400 alternating tooth glass filled split sprocket recommended for this belt.


[9]

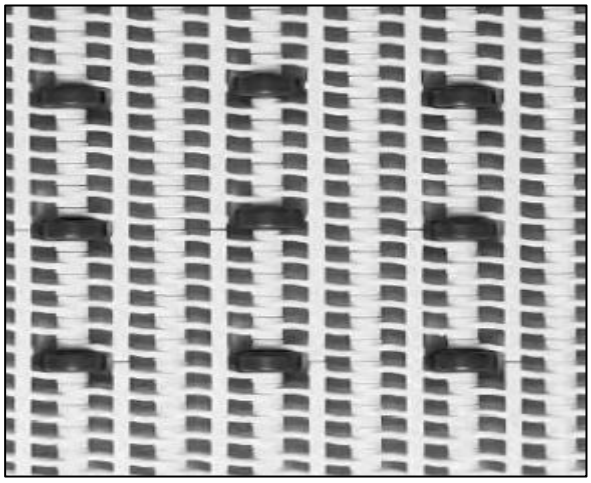
Figure 1. 6 *Alternating tooth glass filled split sprocket*

S900 IR Energy reduction conveyor



[9]

Figure 1. 7 *S900 IR Energy reduction Conveyor*



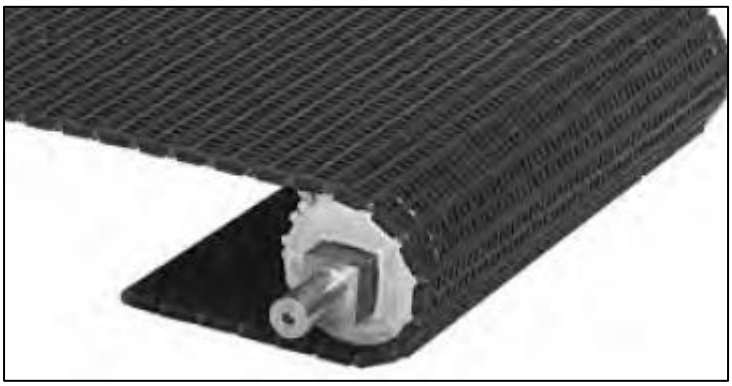
[9]

Figure 1. 8 *S900 IR top view*

IR means Flush Grid with Insert rollers. These kinds of belts are used in where back pressure accumulation is required. It has acetal rollers which are helpful for smooth movement of tires on the conveyor. In this type of conveyor, the sprockets should not be placed in line with rollers.

S900 FG

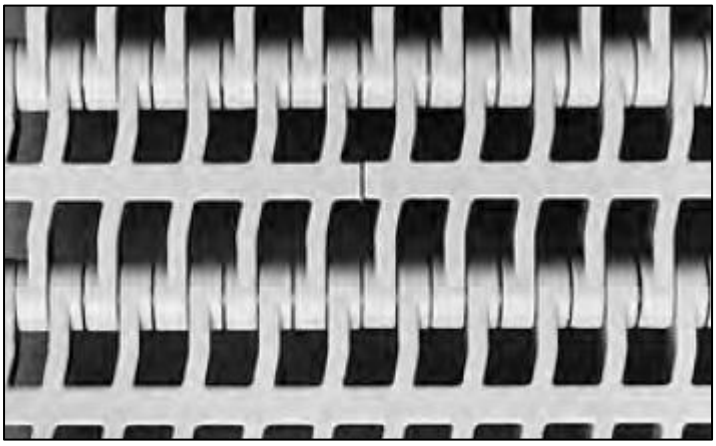
FG means Flush Grid. It has smooth upper surface and Fully flush edges. This type of conveyor gives good lateral movement to the tyres. The rodlets are also made up of the same material.



[9]

Figure 1. 9 *S900 FG*

Reference: Intralox conveyor belt engineering manual



[9]

Figure 1. 10 *S900 FG close-up top view*

Reference: Intralox conveyor belt engineering manual

2. Functional analysis of the controlled system

In this chapter, the performance of the system has been explained. Analysing the functionality of the system once after objecting the aim and needs. This is called functional analysis. In the control cabinet, we have a START pushbutton, STOP pushbutton and a RESET pushbutton. In addition to that we have an Emergency stop pushbutton. We have START, STOP and RESET in the Operating panel also.

2.1 System Functionality

There are six activities has been performed in this project. They are,

i. Safety
ii. Start/Stop
iii. Normal Flow
iv. Accumulation
v. Energy save
vi. Die Back
vii. Sensor Blockage

There are some pre-conditions which are required for the functional activities. Such as the equipment should be stopped, error free and empty. The status of the area on the touch panel will be stopped or OFF (all conveyors are in normal mode/colour).

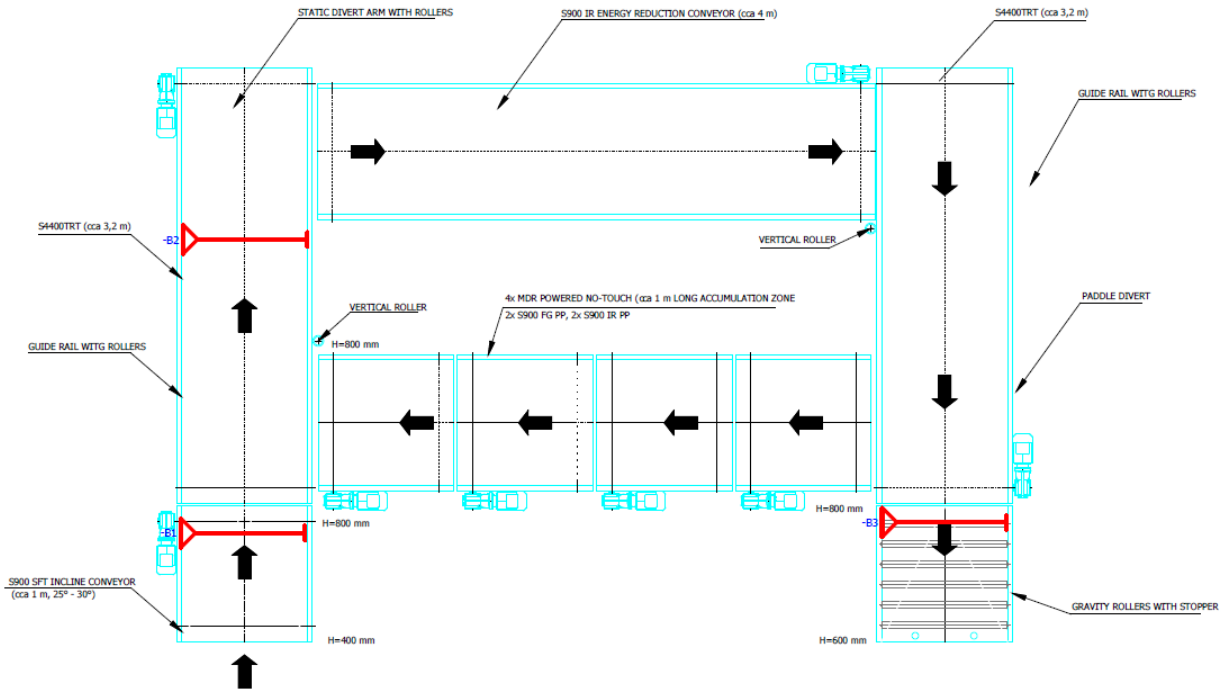


Figure 2. 1 *Layout of the system*

2.1.1 Safety

In the first step of safety functionality, all the pre-conditions should be met. When we start the subsystem, all conveyors are running. The status of the conveyors on the operating panel will be ON (green colour). When you press emergency push button while all the conveyors are running, all the conveyors in the safety zone should stop and the message “Emergency stop” is shown in operating Panel. When you start the subsystem now, nothing will happen. So, we need to release the emergency stop, reset the system and then we can start the system. Now the system will start run and the “Emergency stop” message will disappear from the operating panel.

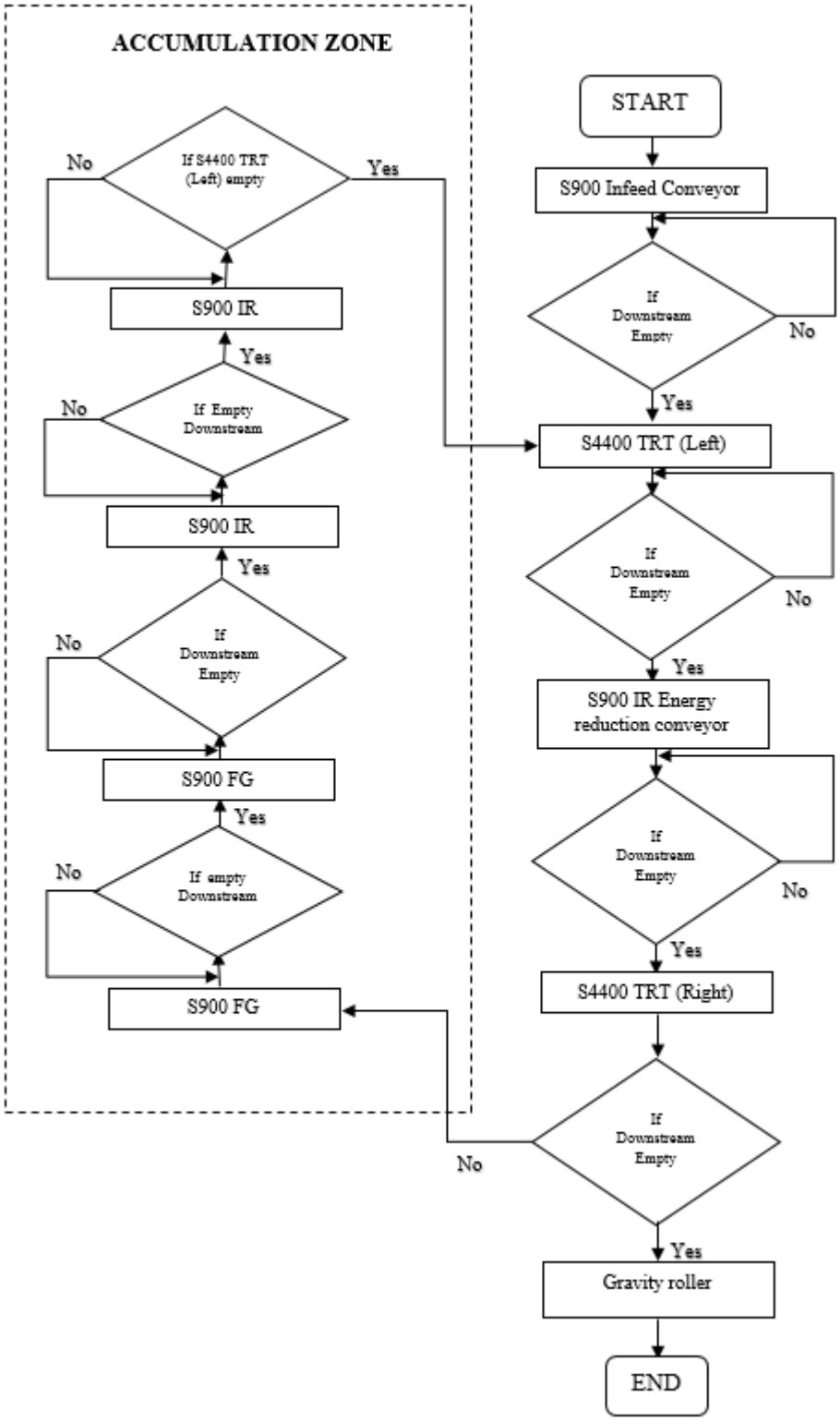
2.1.2 Start/Stop

When you give start command through start pushbutton or the start from operating panel, the general status of the area is shifting from starting to started. During starting of the system, the start-up beeper on the conveyors starts and keep making alert sound for 5 seconds. After 5 seconds, the start-up beeper stops and the system goes from starting to started status. All the conveyors start running for 10 seconds and stop. This start stop procedure is for checking the status of the system (Whether it is free from errors and faults).

2.1.3 Normal Flow

Once the safety and the start-up part are done, now we are in the important part of the project. This part explains the clear working flow process of the system. The below flow chart shows the working flow of the system.

When we place a tire on S900 SFT incline infeed conveyor, the infeed conveyor and the next conveyor S4400 TRT conveyor starts moving. The tire moving on the S4400 TRT conveyor with help of guide rail with rollers (which prevent the tire from scrapping). Now the tire is started moving on to the S900 IR energy reduction conveyor with the help of static diverter arm with roller. By this time when you place a tire on the infeed conveyor, the tire following the previous tire in the same manner. But when the downstream is occupied by a tire, the conveyor has to wait for the downstream clear. When the tire reaches the downstream end of the S900 IR energy reduction conveyor, the S4400 TRT conveyor (right side) starts conveying the tire. There also one more Guide rail with roller which helps the tire to move forward without any scraps. When the tire reaches the downstream of the S4400 TRT conveyor (right side), the tire goes to the gravity roller with a stopper.


ACCUMULATION ZONE
START
S900 Infeed Conveyor
If Downstream Empty
No
Yes
S4400 TRT (Left)
If Downstream Empty
No
Yes
S900 IR Energy reduction conveyor
If Downstream Empty
No
Yes
S4400 TRT (Right)
If Downstream Empty
No
Yes
Gravity roller
END
If S4400 TRT (Left) empty
No
Yes
S900 IR
If Empty Downstream
No
Yes
S900 IR
If Downstream Empty
No
Yes
S900 FG
If empty Downstream
No
Yes
S900 FG

2.1.4 Accumulation Zone

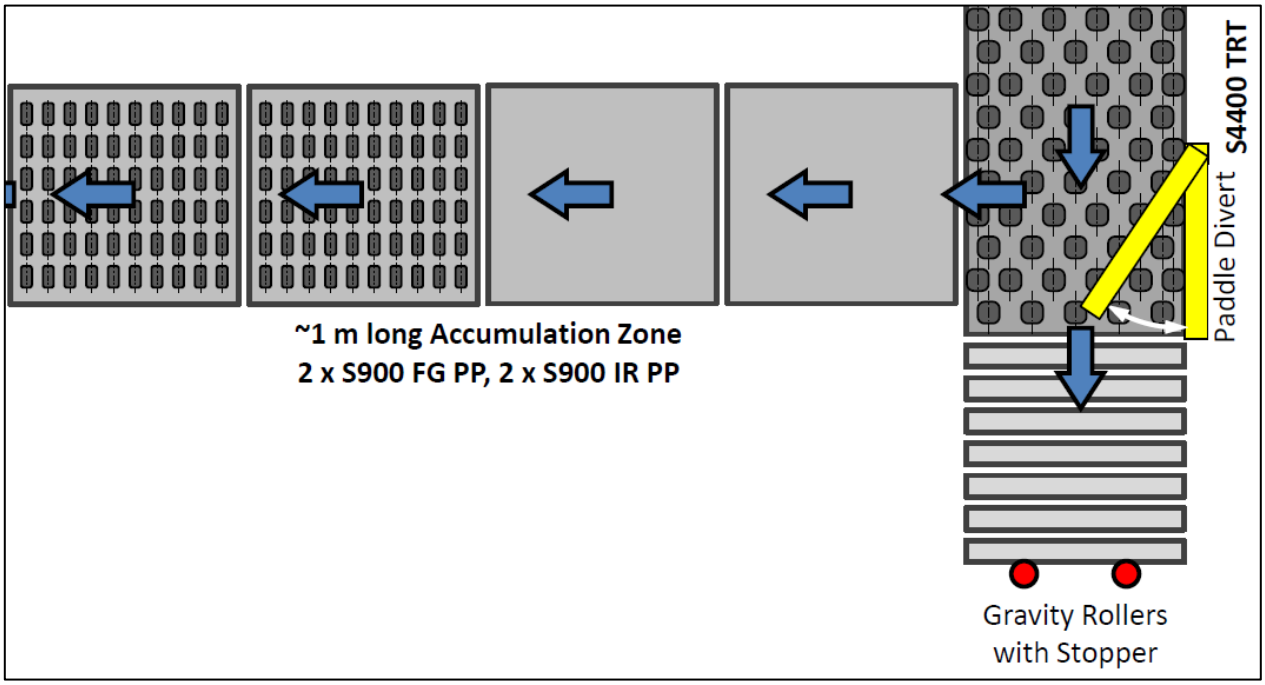


Figure 2. 2 *Accumulation Zone*

Accumulation zone is used for storing the tires if there is a tire on the outfeed gravity roller. If there is a tire on the gravity roller when another tire is moving from S4400 TRT conveyor, the paddle diverter diverts the tire from S4400 TRT conveyor (right side) into the accumulation zone. There are four small conveyors in the accumulation zone. It can store up to four tires. When the tire reaches the last conveyor of the accumulation zone, it will be looking for the allotted window in the S4400 TRT conveyor (left). Once there is no tire on the S4400 TRT conveyor (left), the tire from the last conveyor of the accumulation zone will pass to the S4400 TRT conveyor (left).

2.1.5 Energy save

Energy saving is implemented for all the conveyors which are driven by drivers in the system, they will stop running when there are no tires to be transported. For example, when we place a tire on the conveyor, the conveyor starts running. Once when the conveyor crosses the conveyor, the conveyor stops running automatically (only if there is no baggage from upstream). Each conveyor comes out of the energy saving situation as the tire arrives from upstream section to its downstream. When recovering from energy saving, system shall start without a start-up warning.

2.1.6 Die Back

No conveyor is allowed to discharge a bag into a conveyor that is not running. Die back control shall be implemented for all the conveyors of the system. A conveyor will stop in die-back when a tire is at the downstream conveyor which means the downstream is not ready to receive. The conveyor will restart from die-back when its downstream conveyor is ready to receive.

2.1.7 Sensor Blockage

A blockage is detected if a photocell is occupied during a certain time (longer than the size of the tire to cross through) while the conveyor is running. If a photocell blockage occurs, the conveyor is stopped and an alert message generate on the operating panel. Now the reset and the restart command should be given from the operating panel on the corresponding cabinet. This is consistent with the general error recovery procedure and ensures that resetting and restarting of the system is a responsibility of the controller.

3. Design of Control System

In this project, there are 10 sensors and 8 motor. As there are a smaller number of inputs and outputs in this project, there is no need to go for controllers with many numbers of inputs and outputs. This will increase the cost of the project. So, here is taken a S7-1200 PLC from Siemens. This PLC is a modular type PLC with compacts. Due to the compact modular design with a high performance at the same time, the SIMATIC S7-1200 is suitable for a wide variety of automation applications. Its range of use extends from the replacement of relays and contactors up to complex automation tasks in networks and within distributed structures. It has an inbuilt digital input module and digital output module. A scalable and flexible design, a communication interface that fulfils the highest standards of industrial communication and a full range of powerful integrated technology functions make this controller an integral part of a complete and comprehensive automation solution. The SIMATIC S7-1200‘s integrated PROFINET interface provides seamless communication with the SIMATIC STEP 7 basic engineering system for programming, with SIMATIC HMI basic panels for visualization also.

In S7-1200, there is possibility to connect only 16 input signals and 8 output signals. But here there are more than that of inputs and outputs. In this case, if adding additional module input output module would be costlier and all the devices have to connect by using wires directly from PLC. So, the AS-I communication has been used for connecting inputs and outputs where there are only two wires (one for communication and other for power supply). AS-I is a best way to connect input and outputs as slave devices and we can control it from PLC. Only there is a need of communication module between PLC and AS-I, power supply and AS-I cables.

As the belt width is not more than 150 cm, we can use a photoelectric sensor which can detect the object within the particular width. Here photoelectric Sick sensor with the sensing range from 0 to 150 cm has been used. This sensor is capable to Detect transparent objects, detecting perforated objects, detecting uneven, shiny objects, Detecting objects with position tolerance

MOVIMAT is the best choice for applications where installation space is limited, and where the highest system efficiency is desired. By integrating all components in one housing, it has a uniquely compact construction as a result of integrating the gearing, motor and electronic drive in one housing. It could reduce installation space by 20-25% compared to conventional decentralized solutions, and can be easily integrated into existing material handling systems. MOVIMAT is an efficient and compact solution for material handling systems. MOVIMAT, the gear motor with integrated frequency inverter is used to drive the conveyors. It is a tested combination of gear motor and digital frequency inverter from 0.5 to 5.4 HP power range. Despite this integrated frequency inverter MOVIMAT needs only slightly more space for installation than standard gear motors.

The HMI panel using here is KTP 700 basic which is from Siemens. The main things to select this panel is profinet interface and the configuration as from WINCC and Step-7 TIA PORTAL which are included from Siemens.

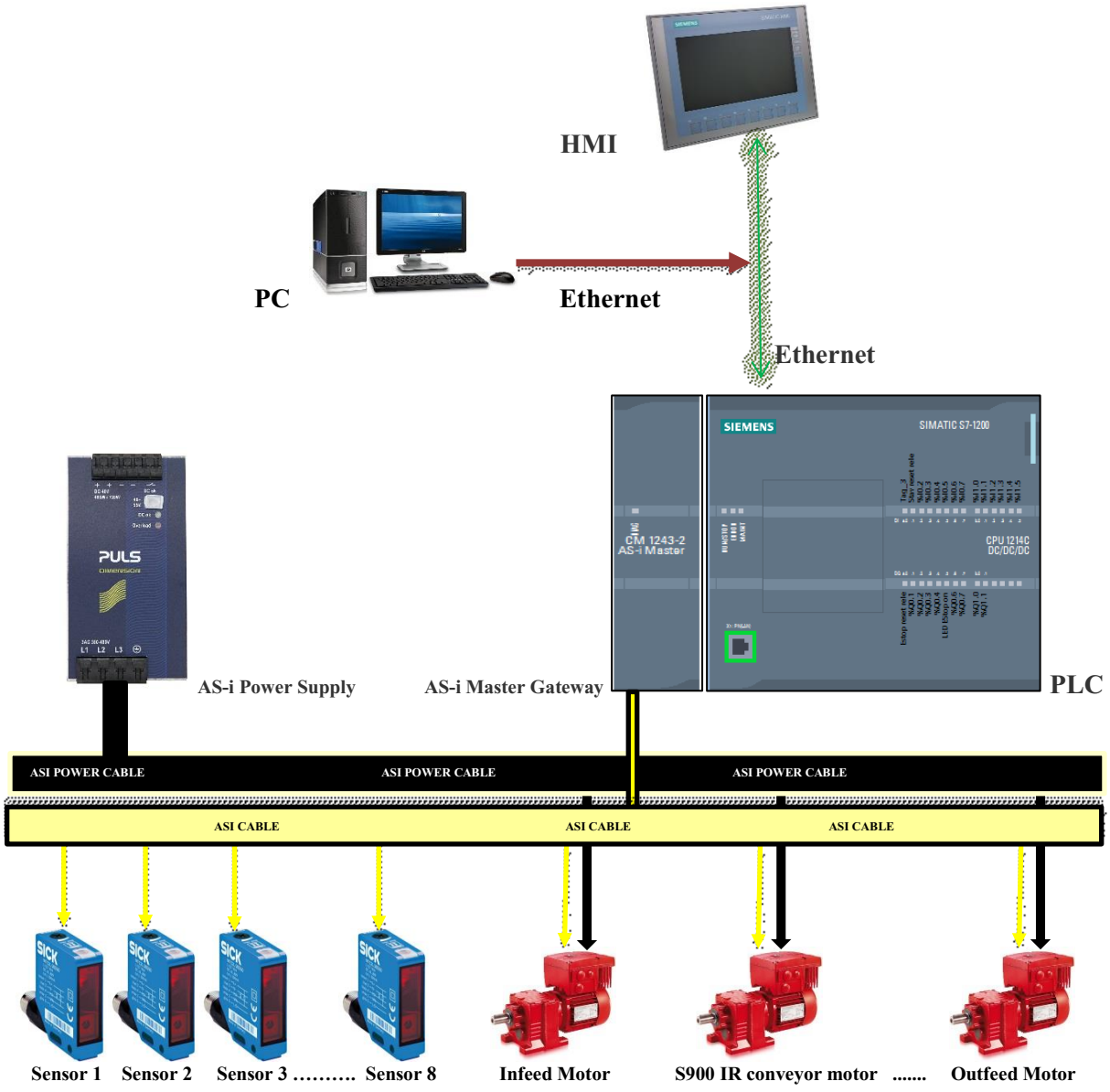


Figure 3. 1 *Control system Design*

The above diagram shows the Operation flow (controlled system) of the project. When a tire is placed on the infeed conveyor, the sensor which is connected with the PLC through ASI interface communication detects and send a Boolean/digital signal to the CPU through ASI interface. Here the CPU is connected with ASI master device which has slave devices for sensors and motor output. When the

CPU gets signal from sensor, it processes the output according to the user program which has been loaded on the memory card through software (TIA PORTAL).

3.1 Programming

The programming of the system is the body of the project, because all the devices in the system will react according to the instruction which has been given to the PLC through software. For programming, Siemens Step-7 TIA PORTAL software version 14 has been used.

In TIA PORTAL, there is possibility to assign all the inputs and outputs (sensors and motors in this project) to tags. These tags are saved in PLC memory. Each and every device will have a separate tag address. For example, the tag of first sensor is saved in the memory bit 0. So, the address mentioned in the TIA PORTAL for the first sensor is I0.0, which means I represents Input, 0.0 represents 0th bit in the 0th channel. That means, each channel has 8 bits (1 byte = 1 channel). The number of channels is depending up on the module what we are buying from Siemens. So as the same for the outputs also. Each of the Motor will have individual tag address in CPU.

3.2 Sensor

Figure 3. 2 *W27-3P3402S17 SICK sensor*

In this project a rectangular shape Sick photoelectric sensor Sick W27-3P3402S17 model has been used. The dimension of the sensor is 24.6 mm x 80 mm x 54.2 mm (W x H x D). It has the sensing range from 0 m to 1.5 m. It needs the distance of 0.5 m to 1.5 m to reflect. It will show a visible red light with pinpoint LED light source. It can handle the supply voltage of 10 V DC to 30 V DC. The power consumption is 35 mA with complementary output function. The response time of this sensor is less than 2.5 sec. Cable with M12 male connector with 4 pins as connection type.

3.3 Programmable Logic Controller

The Programmable logic controller will work according to the program what has been written through software and it has the flexibility to control many types of devices in support of your needs in automation.

3.3.1 Central Processing Unit (CPU)

The S7-1200 PLC from Siemens with CPU (Central processing unit) model "CPU 1214C DC/DC/DC" which has work memory of 100 KB; 24 Volt Direct Current(DC) power supply with 14 Digital input of 24 Volt DC (both Sink and Source connection are possible), also it has 10 Digital output of 24 Volt DC and 2 Analog input on board;

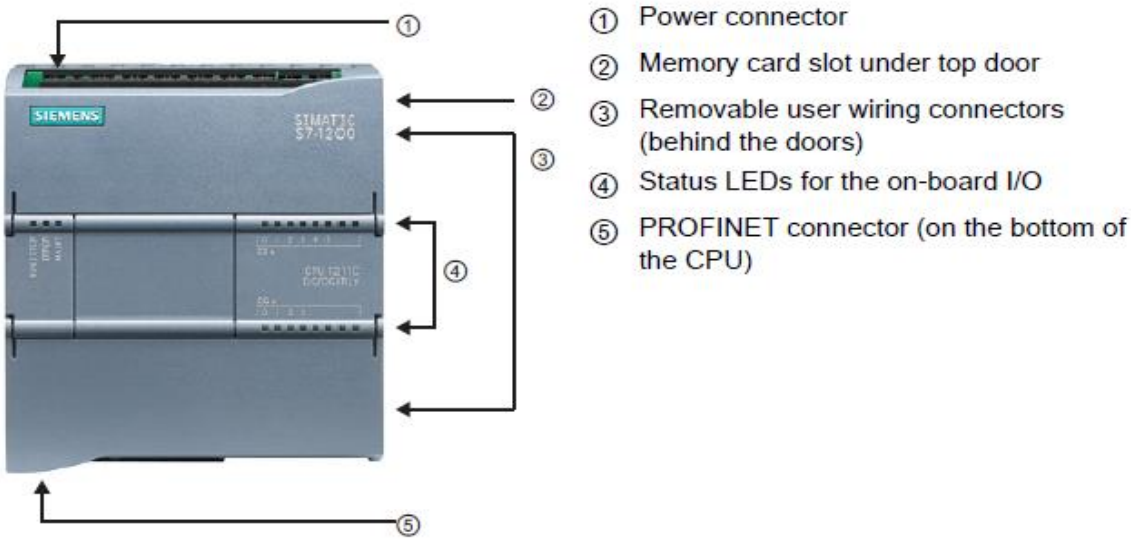


Figure 3. 3 *S7-1200 CPU 1214C DC/DC/DC*

This S7-1200 CPU has a microprocessor along with integrated power supply, input and output circuits, 6 high speed counters and 4 pulse output on board. It has a memory card slot where the programs will be saved. The processor monitoring the input and changing the output stage according to the user program (Includes Boolean logic, counting, timers and other maths operations). It is also possible to have 3 communication modules for serial communication. It takes 0.04 ms/1000 instructions, also profinet interface for programming and PLC to PLC communication. Operation modes of CPU

The CPU of PLC has totally three modes of operation, which are START, STOP and RUN. The modes of these operations are indicated by the status LEDs which are present on the front of CPU.

In START mode of operation, only the block which is related to the Start-up of the operation will execute only once. At that time, no interrupt events are activating. In the Stop mode of operation, we can download the program but the CPU will not execute the program. In Run mode of operation, the program starts executing repeatedly.

3.3.2 Expansion Capability of the CPU

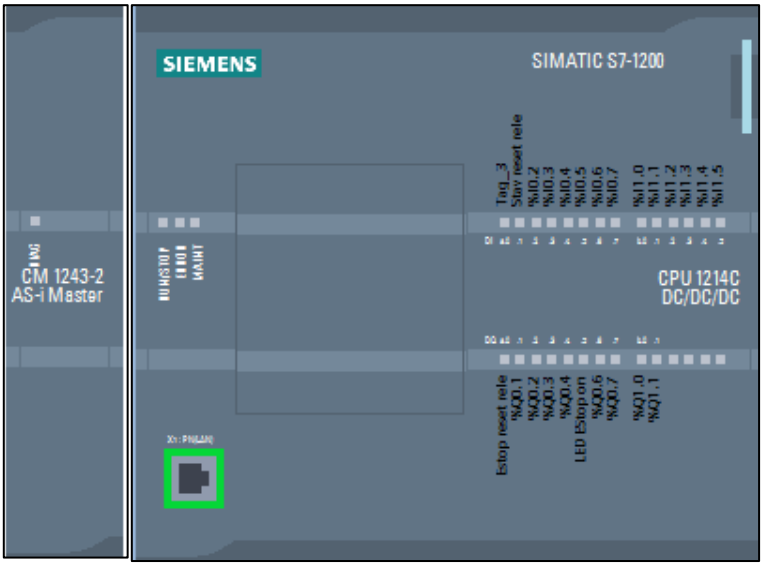


Figure 3. 4 *Expansion module*

S7-1200 gives so many modules for the expansion of protocols. In this project, as you could see above in the figure 2.2 the CPU has an extended additional module to its left side. This module acts as a communication between AS-I gateway and PLC Communication. This type of CPU can support up to 3 additional Communication modules (CM).

[5]

Figure 3. 5 *Communication module*

1. Status LED
2. Communication Connector

There are different types of Communication modules (CM). Such as RS232, RS422/485, Profibus Master, Profibus Slave and AS-I Master (CM 1243-2). In this project we are using AS-I Master/Slave Communication module. There is a communication port in the left side of the CPU module where the Communication module connects. All the sensors and motors are connected with this master module as a slave device through a master gateway.

3.3.3 Operation of PLC

When the CPU input gets logic 1 in the input data table through AS-i interface, the program written by the user will cause logic 1 in the output data table. The logic 1 in the output data table will cause the output module to energize.

When the sensor detects a tire, the input signal in real time is converting to digital electrical signal and connected with PLC through communication cable. These signals from sensor are stored as bits in external memory. The program instructions are written through TIA PORTAL and stored in user memory. The CPU of the PLC reads the instruction one by one from user memory and manipulating, computing, processing the input signals from sensors to operate the output motors. The result of the output is stored in the external memory. This controls the motor device.

The CPU also reads the output signal from motor and updating the status of the input according to the change in the status of the motor. The CPU also has change or resetting in internal programming functions like timer, counter.

3.3.4 Scan Cycle

PLC keeps on scanning the program and repeating the process again and again according to the user program. When the PLC starts, it checks for faults on hardware and software. If there is no fault, it starts the scan cycle. It saves all the binary values of the input in the RAM.

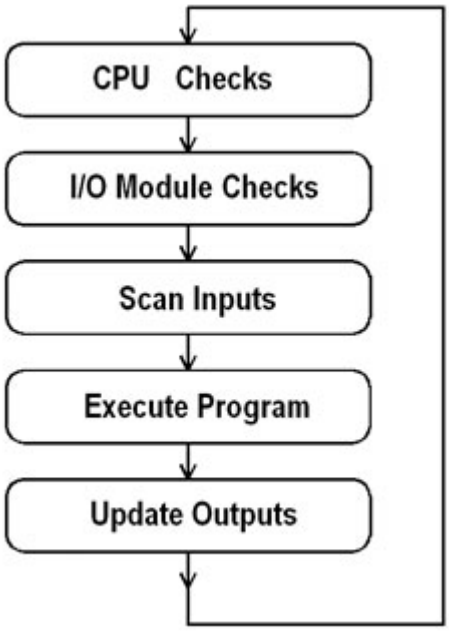


Figure 3. 6 *Scan cycle of PLC*

As you could see above, the PLC scan cycle has three important steps which are scanning of input, scanning of output and the execution of the program.

Input scan

When you place a tire on the infeed conveyor, the sensor in the infeed conveyor detects an object on the infeed conveyor and the status of the sensor is 1. Now the CPU of PLC will save value of the sensor in number 10000000 (when scanning the input). Suppose if the sensor in S900 IR energy reduction conveyor and the infeed sensor detect (First and third conveyor), the value in CPU will be 10100000. Usually the input address depends on the module.

Execute Program

Once the CPU of the PLC checks the all status of the sensors, the PLC will react according to the program that we have written to the PLC through software. For example; the program is like when you place a tire on the infeed conveyor, the status of the sensor in infeed conveyor got to 1. Now the program is written like "IF infeed sensor is 1, THEN infeed conveyor Motor is 1". So, the infeed conveyor motor starts running. These running statuses of the conveyors are saved as the output status in PLC.

Output Scan

When the output status of the conveyor set to be means of program, the output value is represented. For example; when the S900 IR energy reduction conveyor starts running, program will save the number as 00100000. It means 0 as OFF and 1 as ON.

How does the CPU of PLC set the Output?

The memory in the Microprocessor (CPU of the PLC) will have some allocated place for representing the status of the output bit. If we get status 1 for any of the conveyor of the system, the corresponding bit place in the microprocessor will set the bit 0 to 1. Now the corresponding conveyor will start running. When the instruction ends (program finishes), the status of the output will be saved in the corresponding memory bit.

3.3.5 TIA PORTAL STEP-7 Siemens – PLC communication

Once the programming is done, the communication between TIA PORTAL and PLC is done by profibus. By assigning the IP address to the PLC, we can download the program in to PLC from TIA PORTAL. The tags of the input sensors and the output motors are saved to the corresponding address in the PLC modules. The tag of the infeed sensor is saved in the first bit of first channel of the PLC and the tag of the infeed sensor is saved in the third bit of 0th channel of the PLC.

3.4 Human Machine Interface (HMI)

The HMI is a visual interface between human and machine. In this project, there is an HMI panel from Siemens Model "KTP 700 Basic". It is a 7-inch Thin Film Transistor (TFT) display with 800 x 480 pixel, 64K colours; key and touch operation, 8 function keys; one PROFINET port and one USB port.

Figure 3. 7 *Siemens KTP700 BASIC HMI panel*

To design a graphical model of the system, we need software. Siemens also providing WINCC (SCADA software) which is included in TIA PORTAL. Here the design the system has been done according to our specification and needs. Thus, there are possibilities to check the status of our system in operating panel. For this, there is a need to select the proper panel in the WINCC and we have to communicate with PLC and PC

PLC-HMI-PC Communication

For the communication between PC and HMI panel, profinet has been used here. It is same like PLC-PC communication. By assigning the IP address to the HMI, we can download the SCADA to HMI panel from TIA PORTAL. PLC and HMI are connected together by using a profinet. For establishing a connection between runtime simulation at the PG/PC and the S7-1200 CPU.

HMI Tags

Once we designed the model of the system in SCADA, we have to assign the proper tag for the corresponding inputs and outputs. The tags of each component in PLC and the tags of each component in HMI should be same. Otherwise, there will not be a proper communication between the components with HMI.

3.5 AS-i Gateway Communication

AS-I means Actuators Sensor Interface Bus. It has been used for lot of industrial network solutions like physical layer, protocols, data access method etc. Mostly it is used in PLC and DCS based automations systems for connecting field IO devices by using 2 contactor cables.

3.5.1 AS-I Bus network

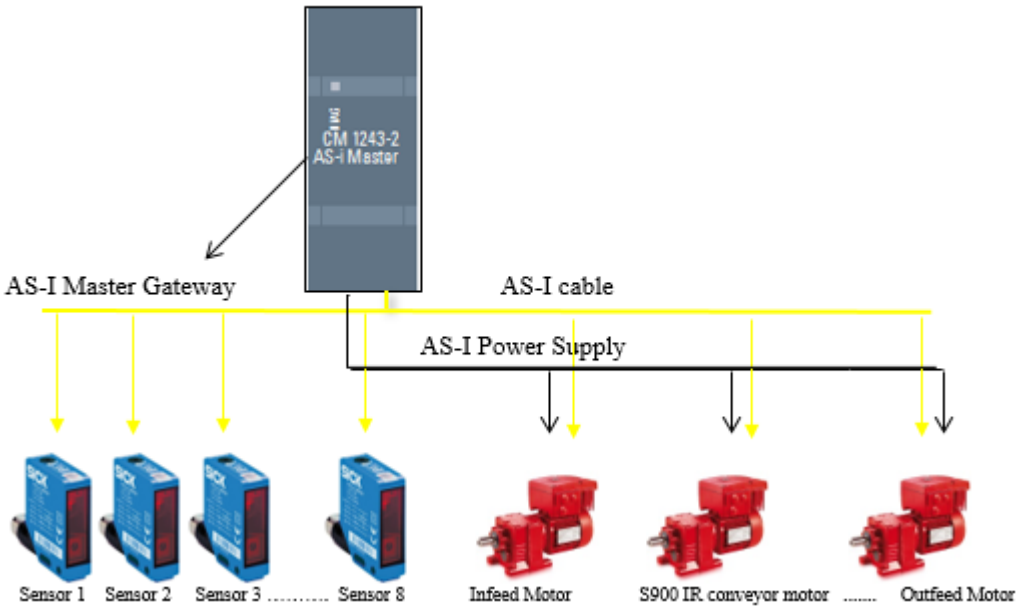


Figure 3. 8 *AS-I networking with slave devices*

As you see in the above diagram, the sensors and motors which are connected with the AS-I Master gateway acts as slave devices. Each of the devices will have individual tag address which is belonging to AS-I Master gateway. All the slave devices are connected with AS-I master gateway through AS-I slave devices. It has only one cable with repeaters. We can connect 62 digital modules in a network and 31 analog modules. Current of 8 A to input and for communication. Communication up to 500 meters possible with repeaters.

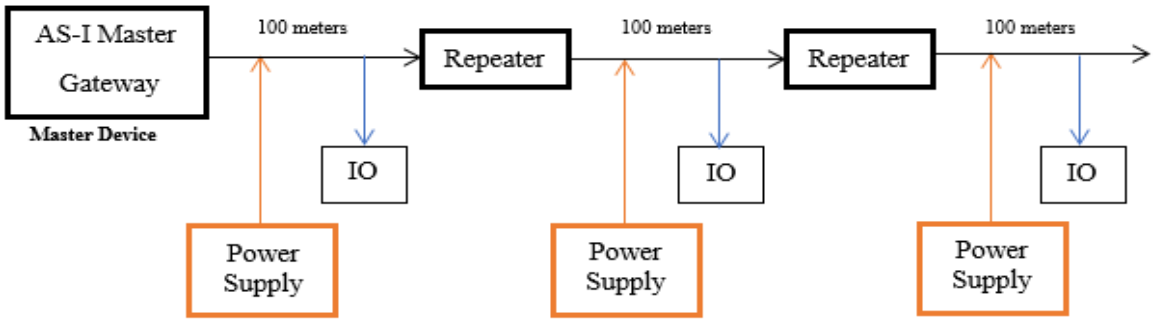


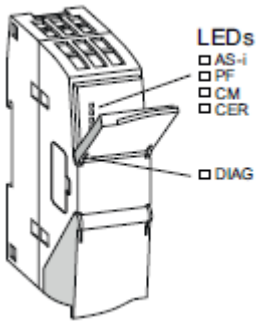
Figure 3. 9 *Block diagram of AS-I Networking*

As you see in the above block diagram, AS-I master gateway plays an important role. It is the major communication between the PLC and the devices. For one AS-I Master Gateway, 100 meters of communication is possible. If you want to connect more devices which are far than 100 meters, we have to use repeaters for every 100 meters. For every 100 meters, we need to connect power supply. Only we could add two repeaters for one gateway. If you need more, we need to add one more master gateway. The most important thing in AS-I bus communication is the power supply and data transfers in same cable. But in this project, as we do not have devices connected above 100 meters; only we need to use AS-I master gateway. No need of repeaters.

3.5.2 AS-I Master CM 1243-2

The master gateway which we are using in this project is CM 1243-2 from Siemens. This acts as an interface between the AS-I and the automating system PLC S7-1200. With the help of CM 1243-2, we can monitor the input sensors and output motors of the system.

LEDs of the AS-I master CM 1243-2



[5]

Figure 3. 10 *Arrangement of the LEDs of the AS-I master*

PF – Peripheral fault

CM – Configuration mode

CER – Error in configuration

DIAG – Diagnosis

Installation, connection and commissioning of the AS-I master CM 1243-2

As a first step we are inserting the AS-I master communication module on the standard 35mm rail in the allotted slot (usually on the left side of the CPU). Then we are connecting the AS-I cable to the master gateway according to the functional wiring guidelines. The connection of the wire is underneath the lower cover of the master gateway module.

The SIMATIC data of the AS-I master gateway module CM 1243-2 is transferring to the real controller PLC while downloading from PC to hardware via Ethernet IP. If the AS-I master gateway is

connected with proper configuration, we can see the property of AS-I master gateway in software. If not, the gateway is not connected properly.

Configuration of AS-I Slave devices

Before configuration, we need to set IO address channels in AS-I master gateway property. So that we can assign individual tag addresses to each AS-I slave devices. Now all the AS-I slave devices are shown in the configuration in TIA PORTAL. Even the parameter changes of the IO are displayed in configuration.

3.5.3 Data exchange between user program and AS-I slaves

To access the information of the data from each sensor in conveyors through AS-I master gateway CM 1243-2. The PLC S7-1200 CPU gets the inputs and outputs of the AS-I slave devices sensors and motors through AS-I master gateway. The data is accessing through IO addressing (IO tags of sensors and motors).

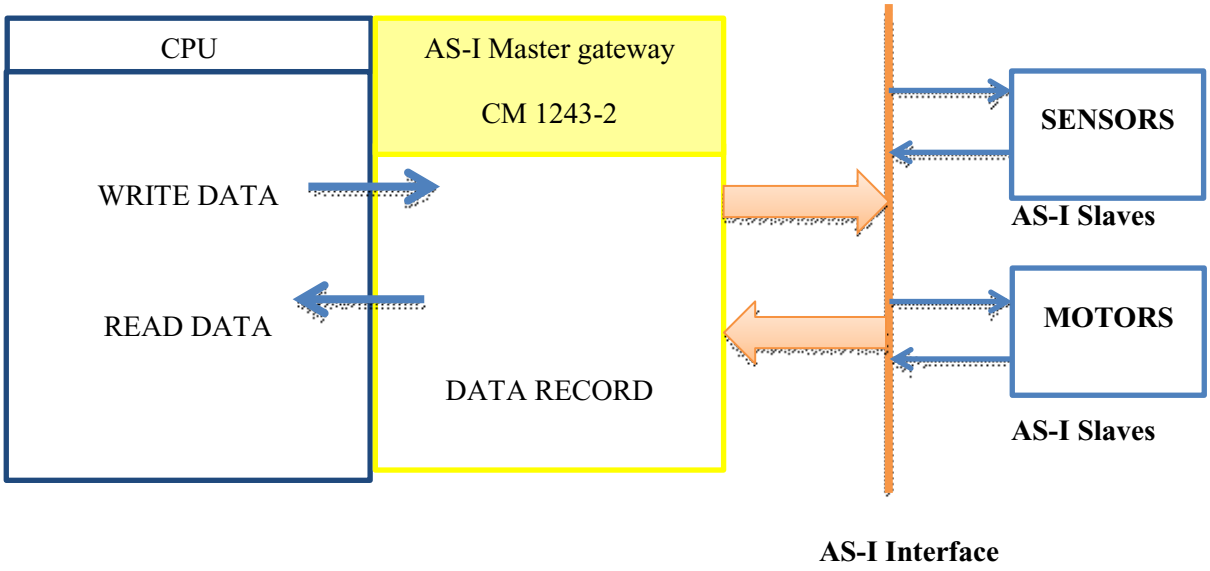
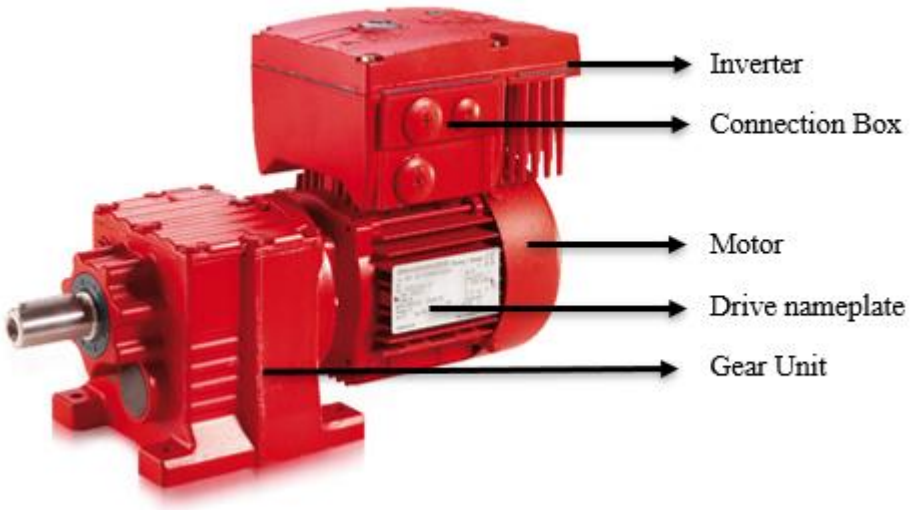


Figure 3. 11 *Data exchange between user programs and AS-I slaves*

3.6 Drive

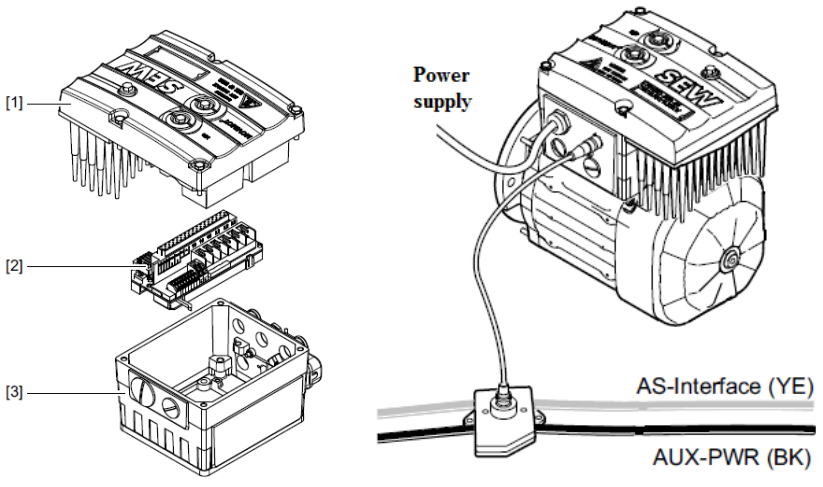
In this system, all the conveyors are driven by SEW MOVIMAT MM05 model motor. MOVIMAT is a combination of inverter, motor and the gear unit. The inverter will be mounted on the motor or it will be mounted next to the motor. The inverter mounted close to the inverter.



[6]

Figure 3. 12 *MOVIMAT Drive*

This Drive has a frequency inverter with power range of 0.37 – 4.0 kW and voltage range 3 * 380 – 500 V. Also, it has a status LED for fast diagnostics. The motor is controlled via binary signal from AS-Interface. There are lot of advantage in using MOVIMAT. It is a compact design which has motor, gear unit and electronics are combined. It has very high system efficiency and very high overload capability. The AS-interface option is inside the inverter connection box. When you open the connection box, you can see the AS-interface option in the connection board.



[5]

Figure 3. 13 *AS-interface option*

1. Inverter
2. Connection board

3. Connection Box

This drive is available for AS-interface designs such as binary slave and double slave (for driving the motor with different set points).

4. Design and implementation of a control application for PLC

In this chapter, the designing of program using TIA PORTAL and the implementation of PLC program to PLC controller via Ethernet communication has been shown.

4.1 Device Configuration

Siemens providing software with library corresponding to the devices. In the first step, the corresponding CPU and modules have been added according to the control design. In the software catalogue, you can find more things like signal boards, communication board, communication modules, Technology modules etc.

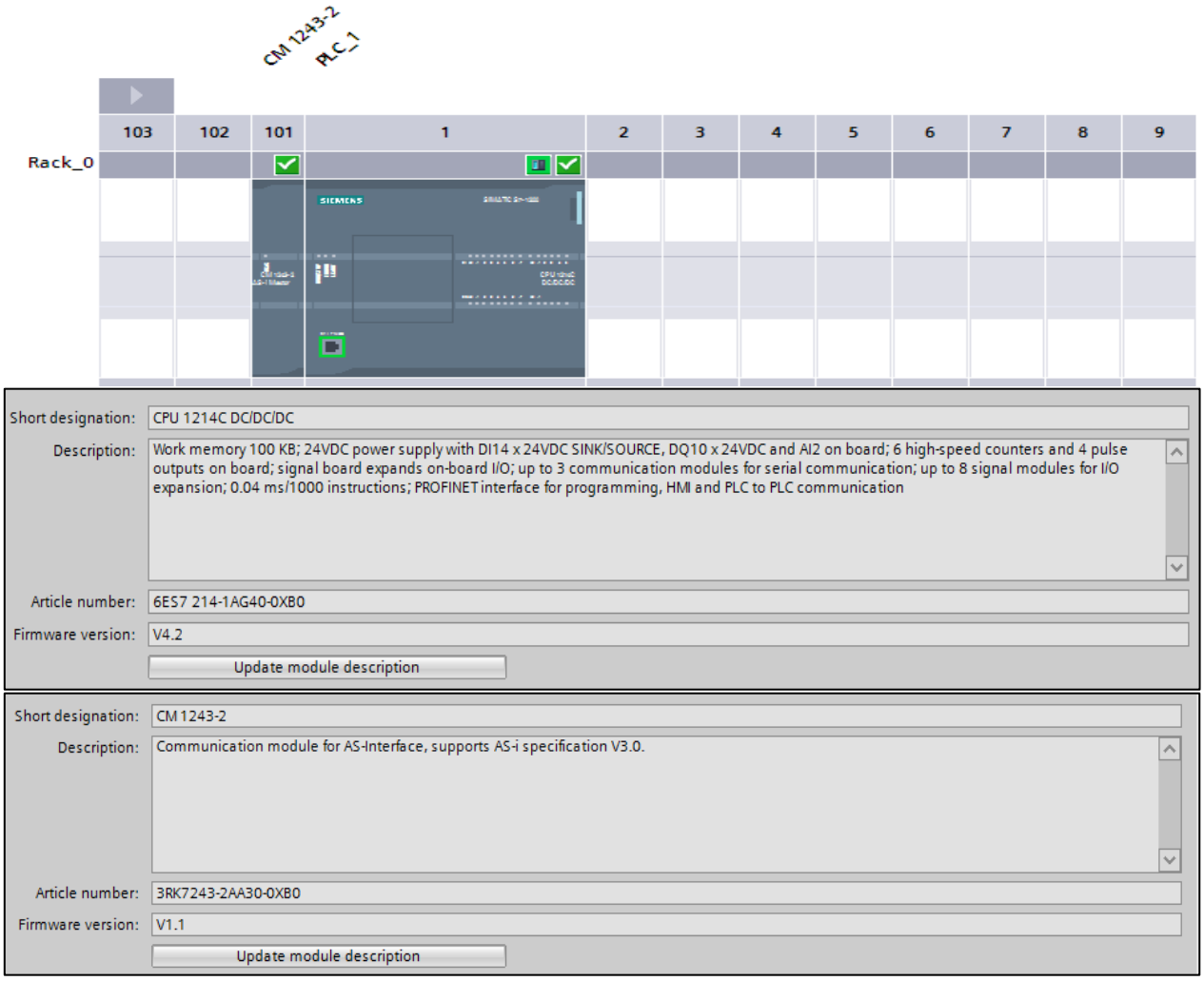


Figure 4. 1 *Device configuration*

In the above figure, the description of our selected PLC controller in the software device configuration have been shown. Same like that, the AS-I master gateway communication module also added in the device configuration.

4.2 Communication between PLC and TIA PORTAL

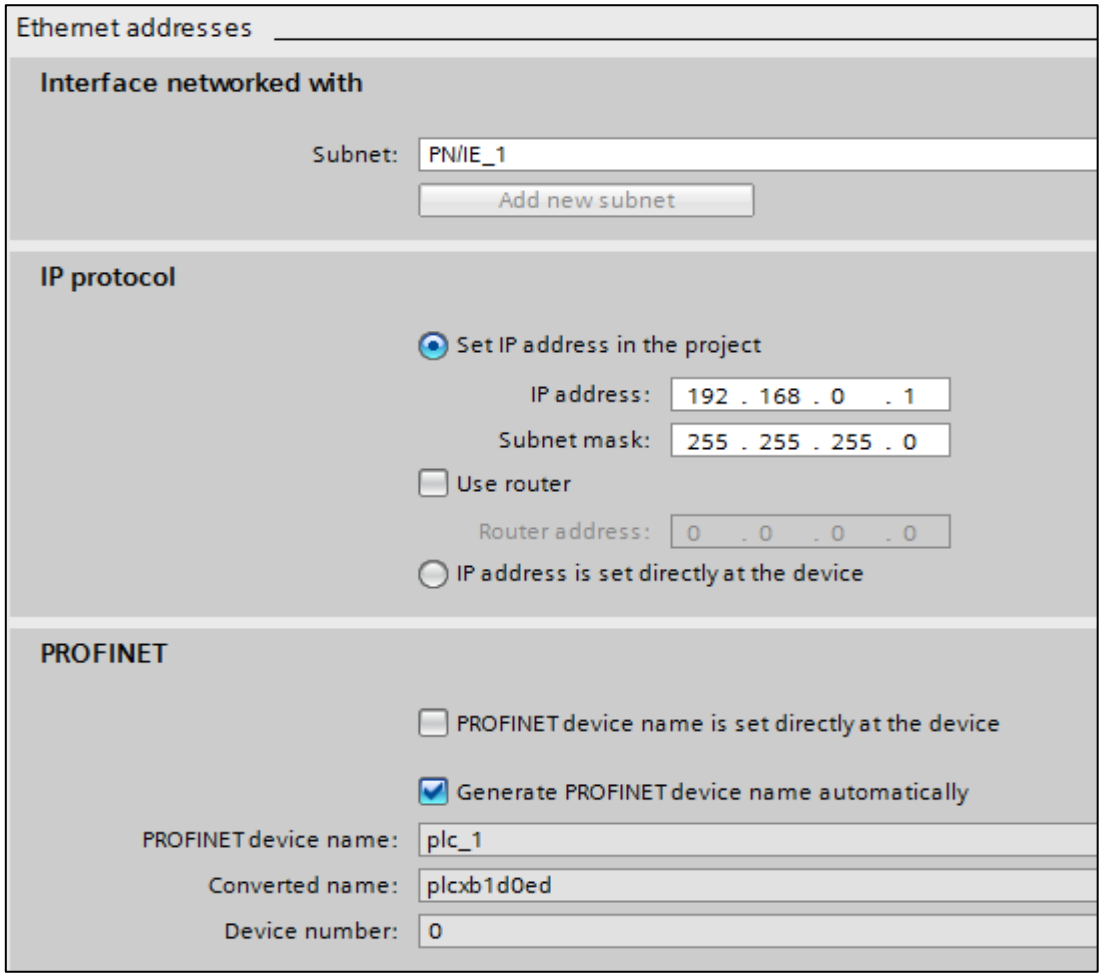


Figure 4. 2 *Communication between PLC and PC*

There is more than one possible way to connect the PLC with PC. Most common are using Ethernet communication and wireless communication. In wireless communication, there will be a router connected with PLC and the PC will be connected to the router IP, by this we can communicate between PLC and PC. Router will act as a communication network between the PLC and the PC.

In the properties of PLC, it is possible to assign the corresponding IP needs to be connected. We are interfacing the network with the subnet PROFINET/INDUSTRIAL ETHERNET with proper IP protocol. There is another option to set the IP address directly at the device. In the online access, you can find the status of your PC connected with PLC and also, we can find the diagnostic status and buffers. In

the profinet interface of online access you can check the network connection (MAC address) and the IP parameters like IP address, subnet mask, default router, IP settings and IP setting time. Device which are connected to an enterprise network or directly to internet must be appropriately protected against unauthorized access.

The device screen shows the current configuration of PLC with PC. In the network view you can see the connection between the devices (if you have more than one station). In the topology view you can see the display and configuration of port connection with Ethernet network in graphical representation.

4.3 Programming

There are many languages to program a PLC such as Function Block Diagram (FBD), Ladder Builder (LAD), Structured Controlled Language (SCL) etc. In this project, the system is programmed by using Ladder Builder (LAD), because LAD is the much familiar language and it is easy to understand too.

4.4 Programming Structure

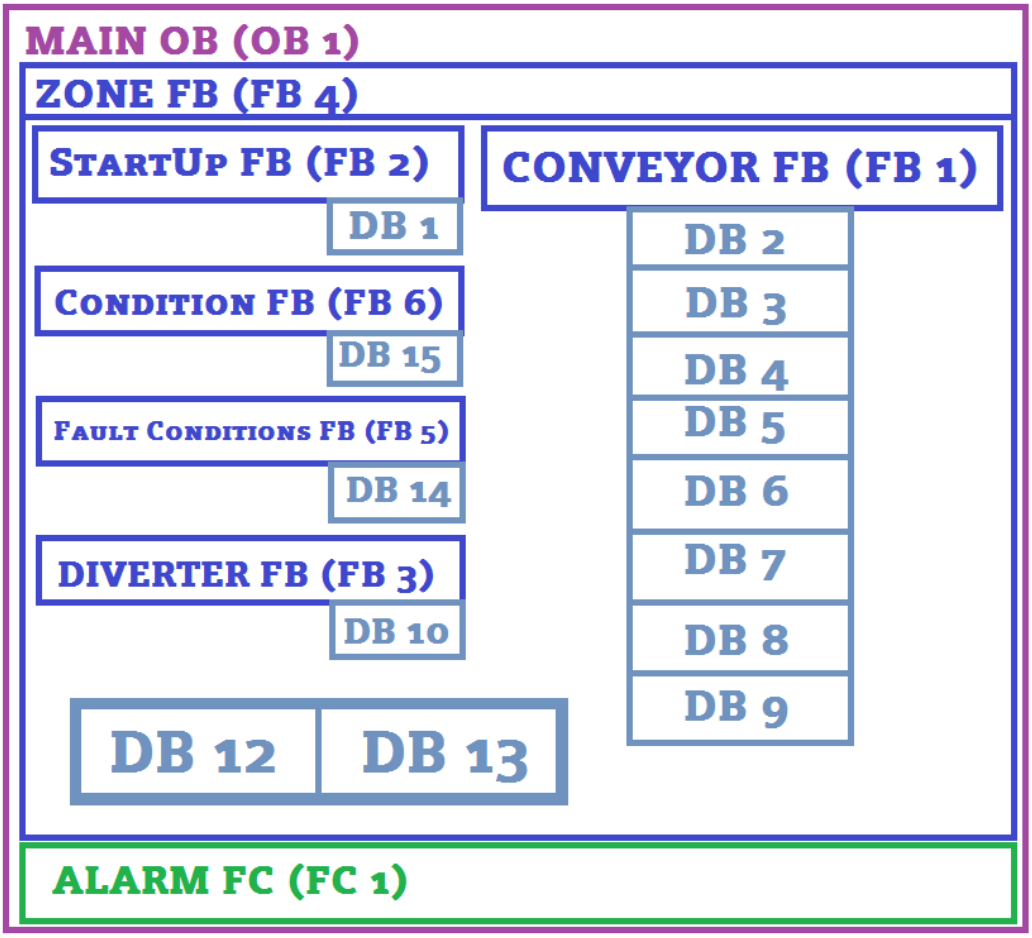


Figure 4. 3 *Programming structure*

Programming must contain everything what are specified in the functional analysis. You define the structure of the user program during the draft phase by adaptation to technological and functional conditions; this is important for program creation, testing, and start-up. In order to achieve effective programming, it is therefore necessary to pay particular attention to the program structure. Analysis of a complex automation task means division of it into smaller tasks or functions based on the structure of the process to be controlled. You define the individual tasks by determining the function and then defining the interface signals to the process or to other individual tasks. You can adopt this structuring of individual tasks in your program. This means that the structure of your program corresponds to the structure of the automation task. As you can see in the above figure, the program has been structured according to the application.

The conveyor FB is the most important block of this project, because all the conveyor will work according to this block. There is a FB has been created for conveyor and calling the conveyor FB with different Data Block DB. There are different two different global DB which has the status and the parameter of each conveyors. The status and the parameter of the conveyors are done by using data types. These data types are used for calling some parameters and status for all conveyors.

4.4.1 Data Type

PLC data type is a structured data type which contain the different data of individual components. You can use the PLC data type to a data structure. If you are using a data structure frequently in programming, you can use PLC data type.

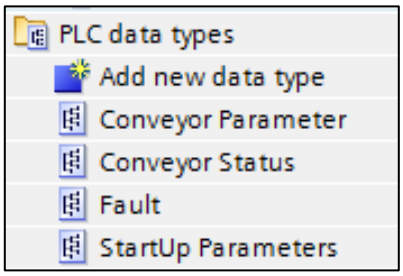


Figure 4. 4 *PLC data type*

Figure 4.4 shows the data types which are used in this programming. Each conveyor has similar parameters, status and fault. So, the created PLC data types of conveyor can be used for all the conveyors. Start-up parameters are used in system start-up function block.

Conveyor Parameter

Conveyor Parameter

Name	Data type	Default value
Sensor Filter Time	Time	T#0ms
Sensor Blockage Time	Time	T#0ms
Clear Conveyor Time	Time	T#0ms

Figure 4. 5 *Conveyor parameter*

i. Sensor Filter Time: The sensor can detect a signal in few ms. So, there is a chance for the sensor to detect a signal even there a small paper or plastic. This parameter helps the sensor to detect only if there is a tire. This sensor filter time is suitable for all the sensors in all the conveyors.

ii. Sensor Blockage Time: There are very less possibilities for tire jam in this project. Even though we are using this tag to detect if there any jam in conveyor system. If the Sensor is blocked for sensor lockage time, the conveyor stops and says that PEC blockage. This sensor blockage time is suitable for all the sensors in all the conveyors.

iii. Clear Conveyor Time: If the status of the conveyor is not ready and every time a tire crosses to downstream from upstream, this timer helps the conveyor to run according to the space.

Conveyor Status

Conveyor Status

Name	Data type	Default value
bReserve 1	Bool	false
bReserve 2	Bool	false
bReserve 3	Bool	false
bReserve 4	Bool	false
bReserve 5	Bool	false
bReserve 6	Bool	false
bReserve 7	Bool	false
bReserve 8	Bool	false
ON	Bool	false
Ready	Bool	false
Running	Bool	false
Occupied	Bool	false
Fault	Bool	false
Estop	Bool	false
Maintenance	Bool	false
Stop	Bool	false

Figure 4. 6 *Conveyor status*

If the start pushbutton is pressed and release, the status of the conveyor will be ON. If you press the stop pushbutton, the status of the conveyor will be OFF (not ON). If you want the status of the conveyor to be READY, the status of the conveyor should be ON with no maintenance status, no ESTOP status, no fault status. When the conveyor is occupied then the status is occupied. Running status will be on if the conveyor is running.

Fault

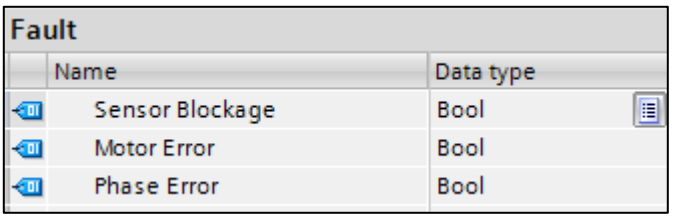


Figure 4. 7 *Fault*

i. Sensor Blockage: If there is jam of tires on conveyor, the status of the conveyor will be fault.
ii. Motor Error: There are possibilities for error in motor. For example, sometime the motor switch will be OFF or it may get some wiring issue. These errors are come under motor error. There is a smart wire from motor to PLC to detect motor error.
iii. Phase Error: If any of the phase missing from 3 phases, it is phase error.

Start-up parameters

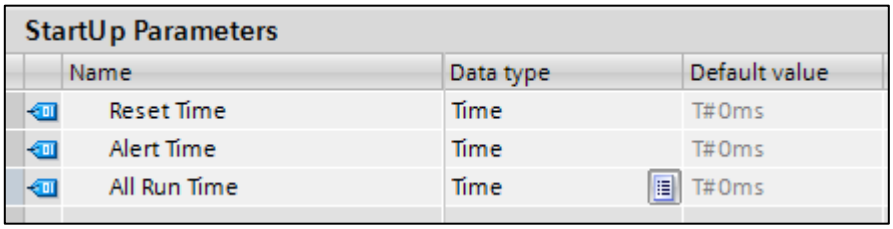


Figure 4. 8 *Start-up parameter*

These parameters are used for system start-up. In the alert time, there will be klaxon yellow glowing and beeper gets ON. Then the beeper and yellow klaxon stop and all the system start running for All Run Time. Reset time is to reset the conveyor to energy save.

4.4.2 Program Blocks

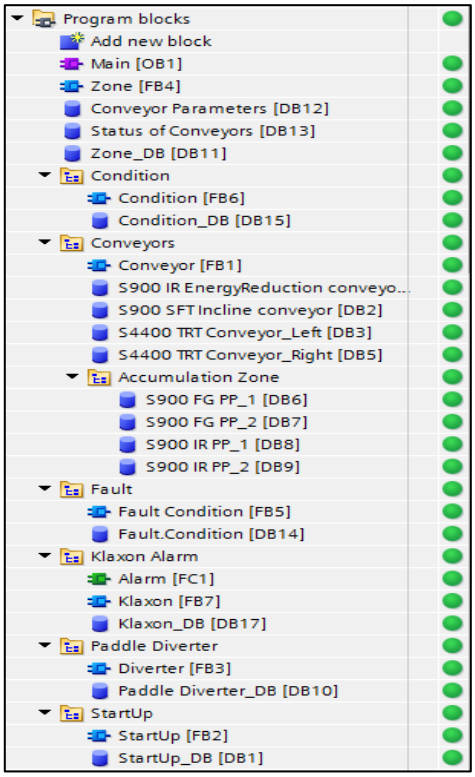


Figure 4. 9 *Program blocks*

The program blocks contain one main organisational block (OB), one function (FC) and many function blocks (FB). The main OB is the communication between the user programming software and the PC. The program which you are doing inside the main OB will be communicated with PC via Main OB. The main OB contains a start-up FB which is used for system start-up operation. The condition FB has few conditions where the upstream conveyor and the downstream conveyor should react according to that condition. The fault condition FB is for telling the upstream and downstream conveyor that the corresponding conveyor has fault. The diverter FB is used for diverting the tires from conveyors to the accumulation zone. There is a conveyor function block which is used for all the conveyors with different data blocks.

Start-up FB

The button ‘Start' will start up the system provided that no general errors (fault, emergency stop, maintenance etc.) are active. When the push button ‘Start’ is operated, a period of time ‘t’ (alert time in start-up parameter data type) will begin during which the klaxon will emit an audible signal with yellow light. After the period of time‘t’ has expired, all the conveyors will be switched on. While the conveyors are being switched on, the ‘Transport On’ light (green klaxon light) will go on and stay on. This also for restarting the system from fault. After recovery of an alarm the specific equipment

must be restarted again. Restart is done by operating the pushbutton 'Start'. Only from an alarm recovered equipment is restarted. When restarting no additional audible signals are emitted.

Conveyor FB

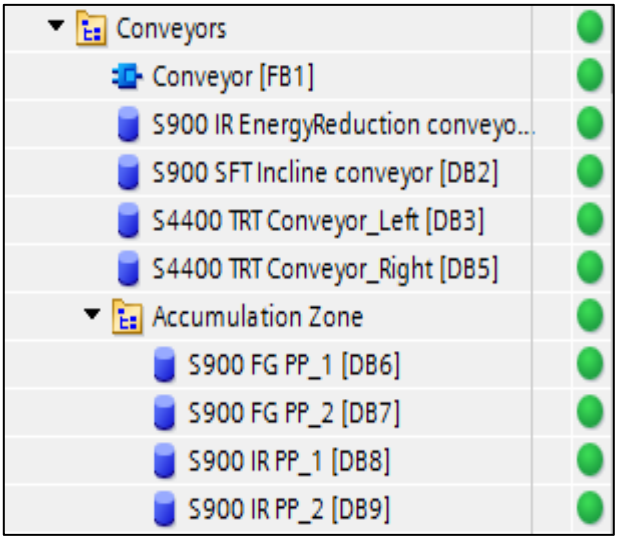


Figure 4. 10 *Conveyor FB*

All the conveyor has similar working, so all the conveyors are working with different data block parameter with different parameters of data types.

Network 1: Sensor Filtering

Sensor will detect only if there is an object. Sensor will send signal after couple of milli seconds.

Network 2: Sensor Blockage

A blockage is detected if a photocell is occupied without tire in downstream and there is no interlock during a certain time (Longer than the item) while the conveyor is running.

Network 3: Checking of all the conditions

If the start Push Button is pressed and release, the status of the conveyor will be ON. If you press the stop Push button, the status of the conveyor will be OFF (Not ON). If you want the status of the conveyor to be READY, the status of the conveyor should be ON with no maintenance status, no ESTOP status, no fault status. When the conveyor is occupied then the status is occupied. Running status will be on if the conveyor is running.

Network 4: Conveyor Occupied

This network contains the conveyor occupied condition. If the conveyor is occupied, the status of the conveyor will be status occupied.

Network 5: Conveyor Working

Set the drive

i. If the conveyor is occupied and the downstream does not have any tire, the motor starts running
ii. If the Upstream is occupied and the conveyor does not have any tire, the motor starts running

Reset the drive

i. If the status of the conveyor is not ready
ii. If the conveyor is occupied and the downstream has a tire
iii. If there any interlock

Conveyors DB

This Data Block is an instance data block. It contains Input, output and static memories.

Input:

In the input of conveyor block, we have some inputs with different data types where PLC will read the devices of the system. First three inputs are common inputs ‘start’, ‘stop’ and ‘reset’. Then we have ‘Estop’ input from Estop pressed. ‘Manual mode’ input is from a switch where you can switch the conveyor mode between manual and automatic. And we will get signal from ‘sensor’, ‘motor error’ and ‘phase error’. ‘Upstream occupied’ is the previous condition to the conveyor and the ‘downstream occupied’ is the next conveyor condition to the present conveyor. Then we have ‘Set Start-up’ and ‘reset start-up’ inputs which are getting pulse corresponding to the start-up FB. Then we are reading the parameter and the status of the conveyor by using PLC Data type. These inputs are only for reading the inputs and the data types or some static from different data blocks. You can see the conveyor parameters and the conveyor status in the figure 4.11.

Name	Data type	Start value	Monitor value
Input			
Start	Bool	false	FALSE
Stop	Bool	false	FALSE
Reset	Bool	false	FALSE
Estop	Bool	false	FALSE
Manual Mode	Bool	false	FALSE
Motor Error	Bool	false	FALSE
Sensor	Bool	false	FALSE
Upstream Occupied	Bool	false	FALSE
Downstream Tire	Bool	false	FALSE
Interlock	Bool	false	FALSE
Set Startup	Bool	false	FALSE
Reset Startup	Bool	false	FALSE
Parameter	"Conveyor Paramet...		
Sensor Filter Time	Time	T#0ms	T#500MS
Sensor Blockage Ti...	Time	T#0ms	T#5S
Clear Conveyor Time	Time	T#0ms	T#10S
Global Status	"Conveyor Status"		
bReserve 1	Bool	false	FALSE
bReserve 2	Bool	false	FALSE
bReserve 3	Bool	false	FALSE
bReserve 4	Bool	false	FALSE
bReserve 5	Bool	false	FALSE
bReserve 6	Bool	false	FALSE
bReserve 7	Bool	false	FALSE
bReserve 8	Bool	false	FALSE
ON	Bool	false	TRUE
Ready	Bool	false	TRUE
Running	Bool	false	FALSE
Occupied	Bool	false	FALSE
Fault	Bool	false	FALSE
Estop	Bool	false	FALSE
Maintenance	Bool	false	FALSE
Stop	Bool	false	FALSE

Figure 4. 11 *Conveyor DB input*

Output:

Output			
Drive On	Bool	false	FALSE
Start Request	Bool	false	FALSE
Ready to send	Bool	false	FALSE
Output Status	"Conveyor Status"		
bReserve 1	Bool	false	FALSE
bReserve 2	Bool	false	FALSE
bReserve 3	Bool	false	FALSE
bReserve 4	Bool	false	FALSE
bReserve 5	Bool	false	FALSE
bReserve 6	Bool	false	FALSE
bReserve 7	Bool	false	FALSE
bReserve 8	Bool	false	FALSE
ON	Bool	false	TRUE
Ready	Bool	false	TRUE
Running	Bool	false	FALSE
Occupied	Bool	false	FALSE
Fault	Bool	false	FALSE
Estop	Bool	false	FALSE
Maintenance	Bool	false	FALSE
Stop	Bool	false	FALSE

Figure 4. 12 *Conveyor DB Output*

Here you can see that the status of the conveyor is been read. 'Drive On' is the output of the motor (running or not). 'Start request' is the request to the next conveyor from the present conveyor. 'Ready to send' is for checking the next conveyor whether it has tire or not.

Fault DB

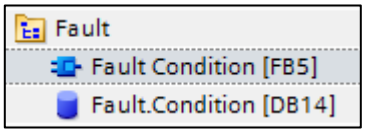


Figure 4. 13 *Fault condition FB & DB*

In this block, there are conditions to the upstream and downstream conveyor how should it react to the fault in upstream and downstream conveyors. Basically, if the status of the next conveyor is not ready, the upstream conveyor stops running when the tire reaches the photocell of the upstream conveyor.

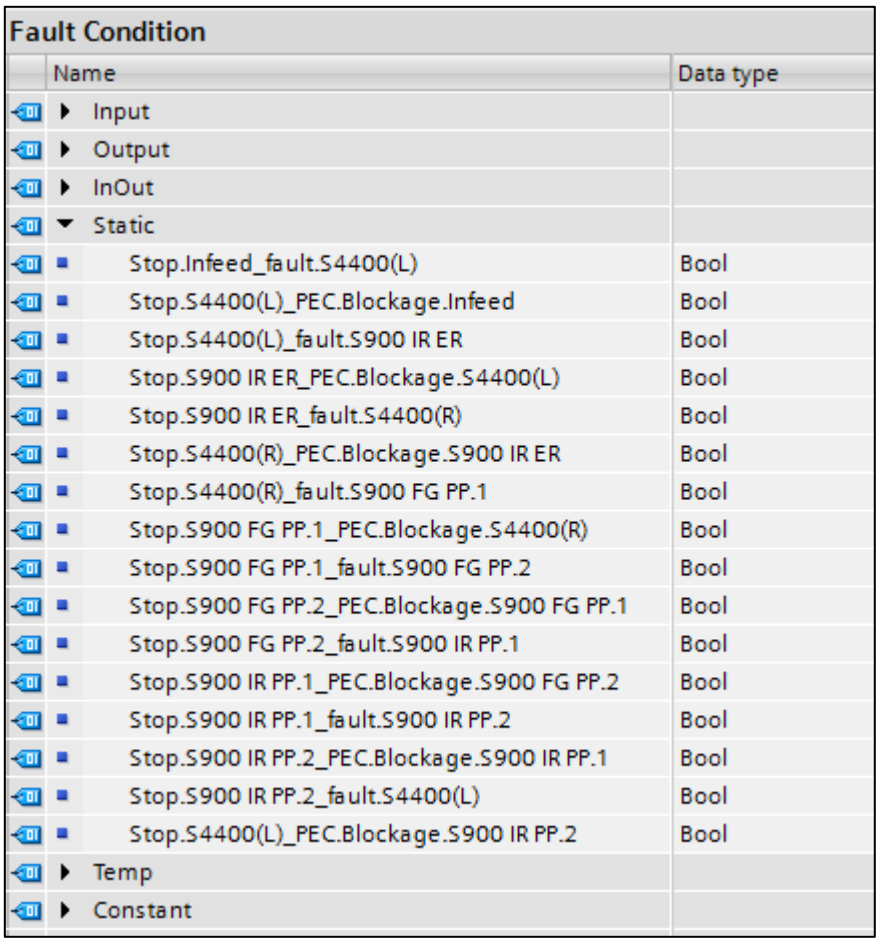


Figure 4. 14 *Fault condition DB*

This block gets the status of all the conveyors from conveyor parameter global data block and apply interlock condition to the upstream and downstream conveyors. The conditions are given into a static memory. There is a static condition for each and every fault. For example, first condition in figure 4.14 says that “Stop Infeed SFT Incline Conveyor, because there is a fault in conveyor S4400 (Left)” and so on.

Global DB

Conveyor Parameters

Conveyor Parameters

	Name	Data type	Start value	Monitor value
	Static			
	S900 SFT Incline Conveyor	"Conveyor Paramet...		
	S4400 TRT Conveyor_Left	"Conveyor Paramet...		
	Sensor Filter Time	Time	T#0ms	T#500MS
	Sensor Blockage Time	Time	T#0ms	T#10S
	Clear Conveyor Time	Time	T#0ms	T#10S
	S900 IR Energy Reduction C...	"Conveyor Paramet...		
	Sensor Filter Time	Time	T#0ms	T#500MS
	Sensor Blockage Time	Time	T#0ms	T#10S
	Clear Conveyor Time	Time	T#0ms	T#10S
	S4400 TRT Conveyor_Right	"Conveyor Paramet...		
	S900 FG Conveyor_1	"Conveyor Paramet...		
	S900 FG Conveyor_2	"Conveyor Paramet...		
	S900 IR PP Conveyor_1	"Conveyor Paramet...		
	S900 IR PP Conveyor_2	"Conveyor Paramet...		
	Paddle Diverter	"Conveyor Paramet...		
	StartUp	"StartUp Parame...		

Figure 4. 15 *Conveyor parameters global DB*

In the global DB of all conveyor parameter, we are calling the data type 'Conveyor Parameter' for all the conveyors. By using this created data types, we do not need to give parameters every time to each conveyor. As you are seeing in figure 4.15 'Sensor Filter time', 'Sensor Blockage time' and 'clear conveyor time' is suitable for each of the conveyors. You can change the parameters of each conveyors according to the conveyor working.

Status of the Conveyors DB

Status of Conveyors

Name	Data type	Offset	Start value	Monitor value
Static				
S900 SFT Incline Conv...	"Conveyor Status"	0.0		
S4400 TRT Conveyor_...	"Conveyor Status"	2.0		
bReserve 1	Bool	2.0	false	FALSE
bReserve 2	Bool	2.1	false	FALSE
bReserve 3	Bool	2.2	false	FALSE
bReserve 4	Bool	2.3	false	FALSE
bReserve 5	Bool	2.4	false	FALSE
bReserve 6	Bool	2.5	false	FALSE
bReserve 7	Bool	2.6	false	FALSE
bReserve 8	Bool	2.7	false	FALSE
ON	Bool	3.0	false	TRUE
Ready	Bool	3.1	false	TRUE
Running	Bool	3.2	false	FALSE
Occupied	Bool	3.3	false	FALSE
Fault	Bool	3.4	false	FALSE
Estop	Bool	3.5	false	FALSE
Maintenance	Bool	3.6	false	FALSE
Stop	Bool	3.7	false	FALSE
S900 IR Energy Reduct...	"Conveyor Status"	4.0		
S4400 TRT Conveyor_...	"Conveyor Status"	6.0		
S900 FG Conveyor_1	"Conveyor Status"	8.0		
S900 FG Conveyor_2	"Conveyor Status"	10.0		
S900 IR PP Conveyor_1	"Conveyor Status"	12.0		
S900 IR PP Conveyor_2	"Conveyor Status"	14.0		
Paddle Diverter	"Conveyor Status"	16.0		

Figure 4. 16 *Status of the conveyors DB*

In the global DB of all status of the conveyor DB, we are calling the data type 'Conveyor Status' for all the conveyors. By using this created data types, we do not need to give status of the conveyors every time to each conveyor. As you are seeing in figure 4.16 all the status of the conveyors is suitable for all the conveyors. All the status of all the conveyors according to the output conveyor status where the status of the conveyors is written in output of all conveyor blocks. You can see the offset of all the status of the conveyor.

Alarm FC

HMI_Alarm_Tag

Name	Data type	Address
Alarm SFT Incline Conveyor_Word	Word	%MW10
Motor Error SFT Incline Conveyor	Bool	%M11.0
Phase Error SFT Incline Conveyor	Bool	%M11.1
PEC Blockage SFT Incline Conveyor	Bool	%M11.2
Alarm Spare 1	Bool	%M11.3
Alarm Spare 2	Bool	%M11.4
Alarm Spare 3	Bool	%M11.5
Alarm Spare 4	Bool	%M11.6
Alarm Spare 5	Bool	%M11.7
reserveAlarm 1	Bool	%M10.0
reserveAlarm 2	Bool	%M10.1
reserveAlarm 3	Bool	%M10.2
reserveAlarm 4	Bool	%M10.3
reserveAlarm 5	Bool	%M10.4
reserveAlarm 6	Bool	%M10.5
reserveAlarm 7	Bool	%M10.6
reserveAlarm 8	Bool	%M10.7

Figure 4. 17 *HMI alarm tag*

Alarm FC (Function) block is used for performing alert by giving audible klaxon audio and klaxon yellow colour. As you are seeing in the figure 4.17, these are the tags of alarm. Here a data type word for each conveyor has been created and using a triggering bit for each and every faults and error that the conveyor will face. In the above figure, there are some tags given when should the alarm should turn ON.

4.4.3 Why Reserve bit?

You can see reserve bits in conveyor status and in Alarm tags. When writing alarms in this way the first segment must be always the reset block. This because even if you reset all the alarms pushing the reset button, if one fault condition is active, the alarm will be settled again few segments later, resulting in a still active alarm at the end of the program. The last part is a recap of all alarms, really useful while debugging because you can notice instantly what's going on just by watching 1 segment. The first bit of the word alarm has been chosen as "no active alarms" because usually: Alarms starts from number 1 and continues, so it's no use to have an offset among alarms and bits. This bit triggers all the alarms-screens and alerts on HMI and Scada.

4.4.4 Downloading

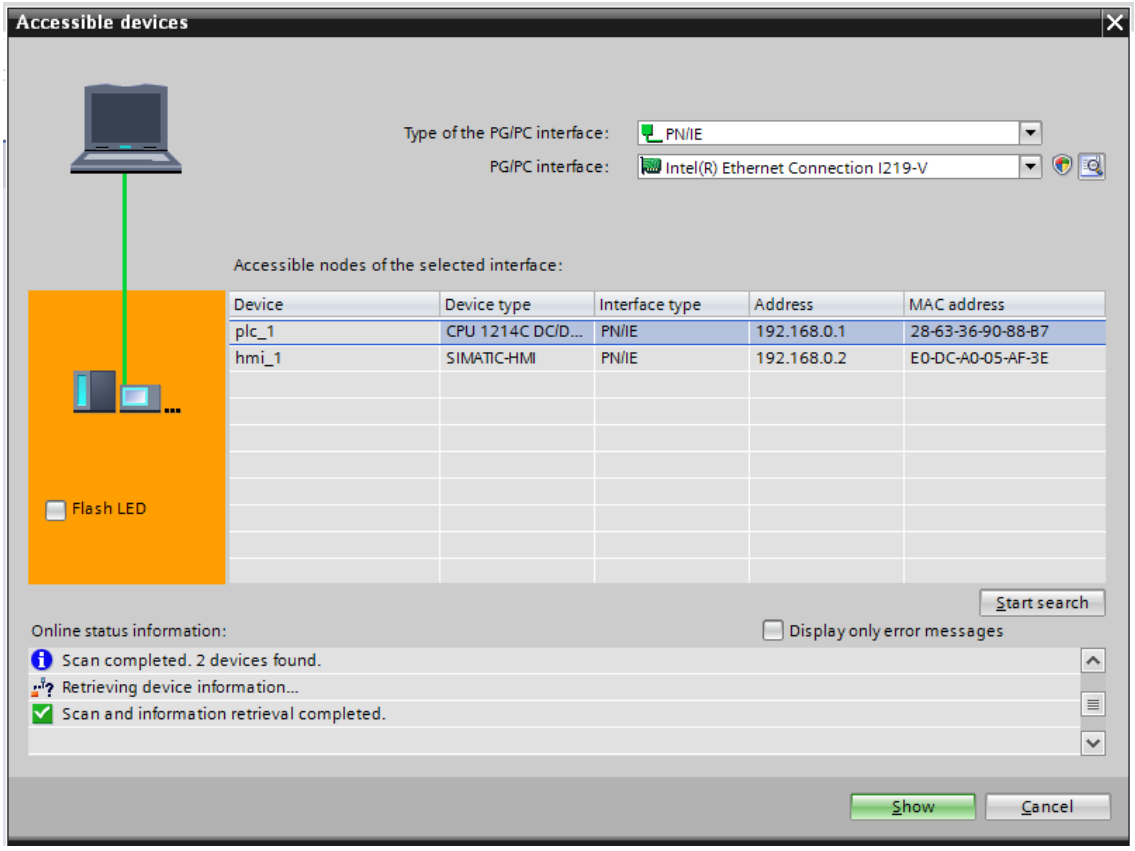


Figure 4. 18 *Downloading from PC to PLC*

In this extend of download the program to device, the program will be loaded to the controller through Ethernet connection. The software will be looking for the PLC through the IP address and it will start downloading the program into PLC. Make sure that the type of PG/PC interface is PN/IE through Ethernet connection and change the connection to the subnet slot. Start your search, find your PLC and load your program.

5. Design and implementation of a control application for HMI

Same like PLC, HMI panel communicate with PC through Ethernet via IP address. It has 7" TFT display, 800 x 480 pixels, 64K colours; Key and Touch operation, 8 function keys, one PROFINET communication port and one USB Commination port.

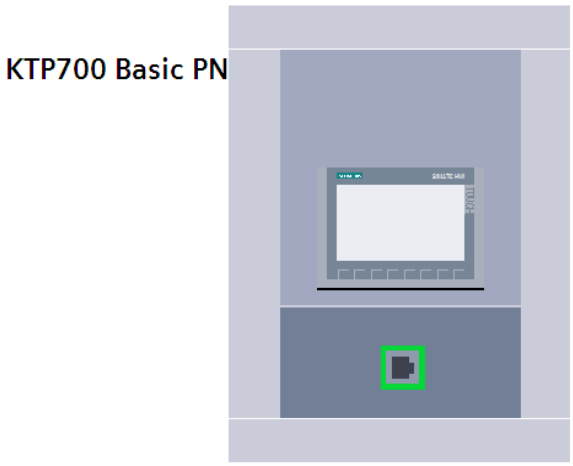


Figure 5. 1 *KTP700 Basic panel*

5.1 Screens

In this project, there are different screens has been used for different functions. There is one main Screen and 4 additional screens for other functions. Such as Main Screen, Alarm, Alarm History, Legend and one for checking the fault in conveyors.

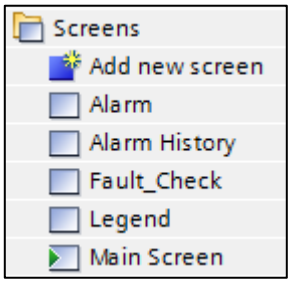


Figure 5. 2 *Screens of HMI*

5.1.1 Main Screen

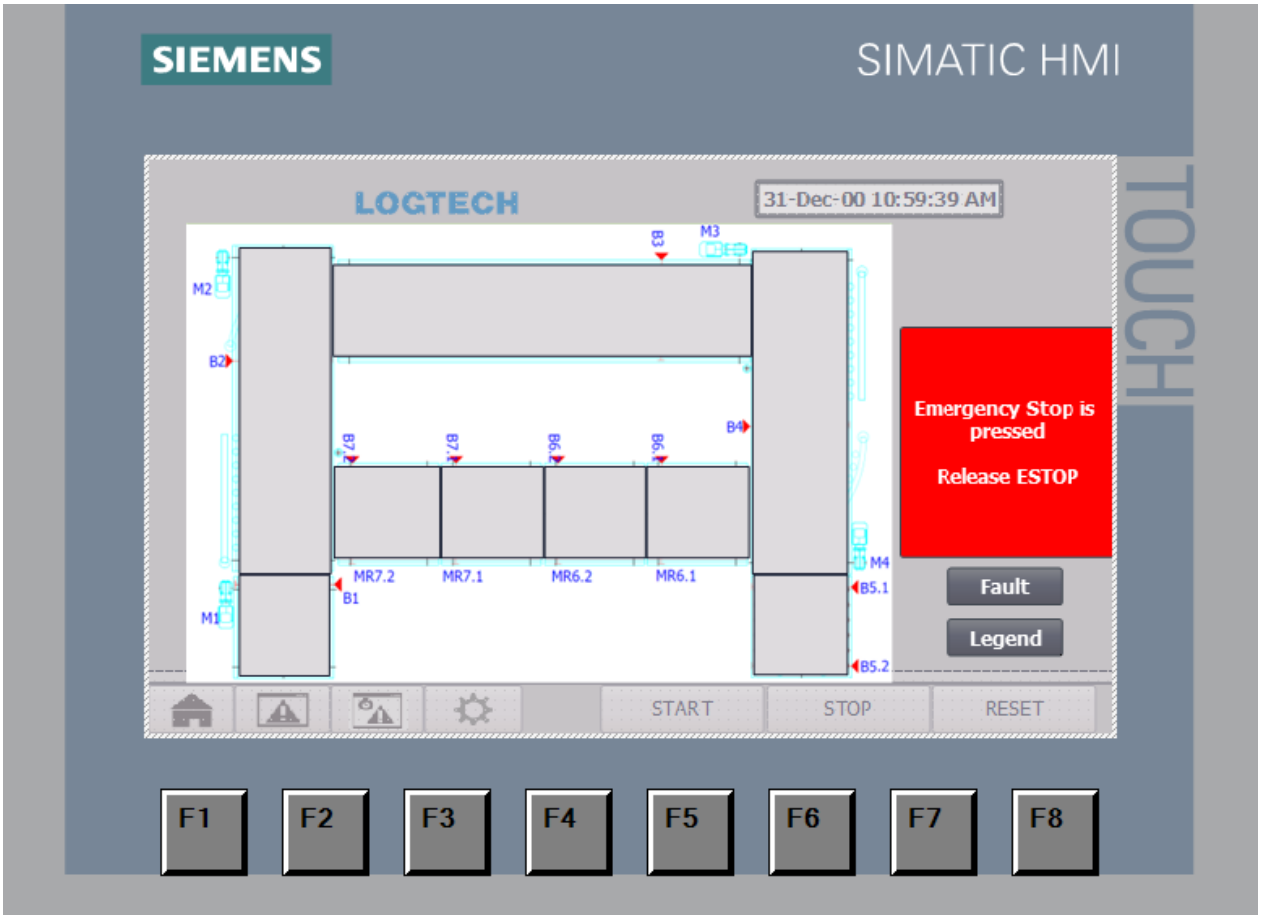


Figure 5. 3 *Main screen of HMI*

In the main screen, you can see the complete layout of our system. Background image shows the mark indications of sensors and motors. In the top and the bottom of the screen we have the screen management. The element 'Fault' which is at the right bottom of the screen will take you to the fault screen where you can see which conveyor is under fault condition. We also have an element 'legend' which will take you to the legend screen where all the legends are been explained. The red big box will be activated or blink only if the emergency stop is pressed.

In the tag connection of HMI object with PLC tag, appearance and visibility can be adjusted according to the application. In the figure 5.4, you can see the appearance of Conveyor and the visibility of the Emergency stop situation. The most important thing in HMI is tag connection. We should select the correct tag of PLC to HMI for corresponding Conveyors. The conveyor will be in grey colour if the conveyor is not running and if the conveyor is occupied and running, it will be in green colour. Green colour shows the running status of the conveyor and the grey colour shows the resting status of the conveyor. Emergency stop object will be visible only if the emergency stop pushbutton is pressed; which means the bit change from 0 to 1.

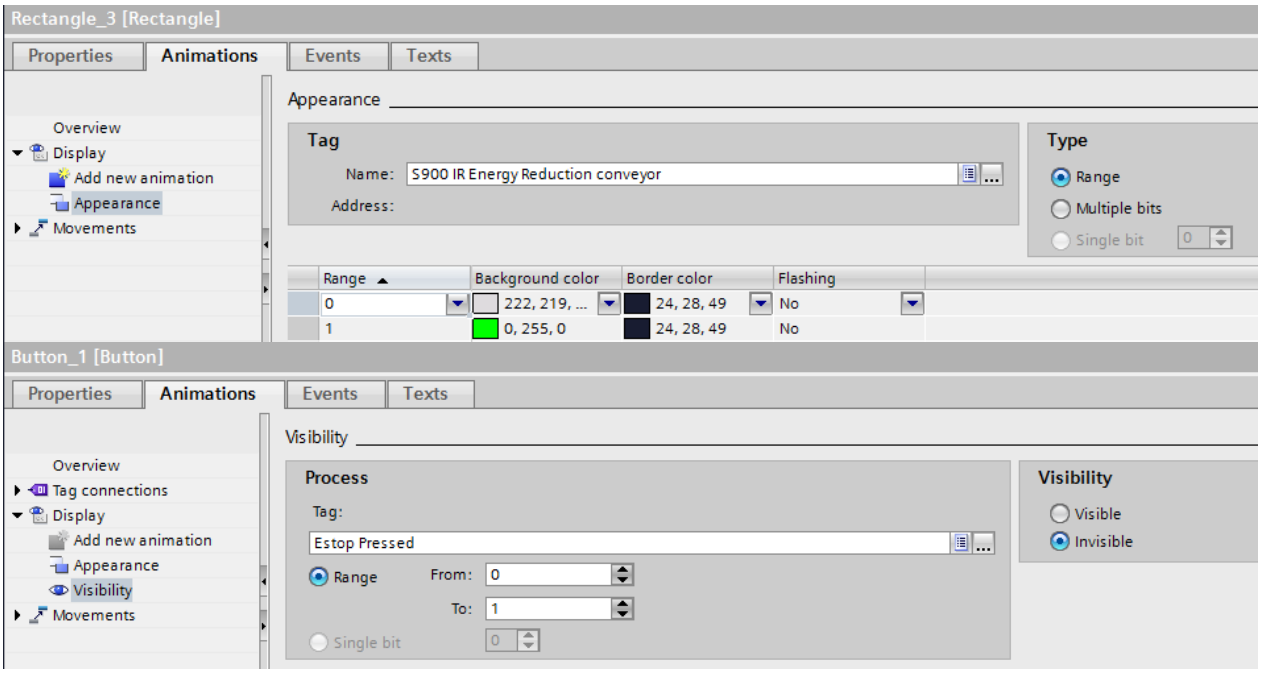


Figure 5. 4 *Tag connection*

5.1.2 Screen Template

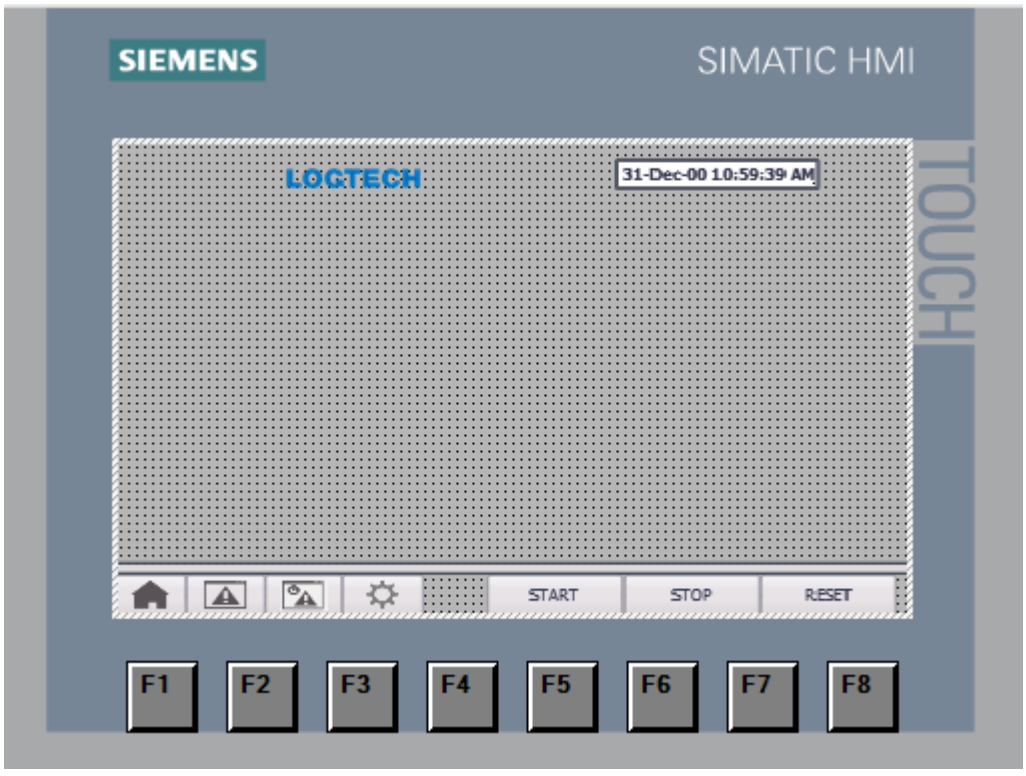


Figure 5. 5 *Screen template*

Template screen can be used as a template for more screens. No possibilities for make changes are template screen from other screens. If you need to make changes in template screen, you have to open the screen management and should make changes in template screen. We have set the START, STOP and RESET memory bits to corresponding objects on the panel. There are some other icons;

The home icon active the Home screen

This icon active the current Alarm Screen

This icon active the alarm history screen

This icon active the runtime screen of the system

This will show the system time

For example,

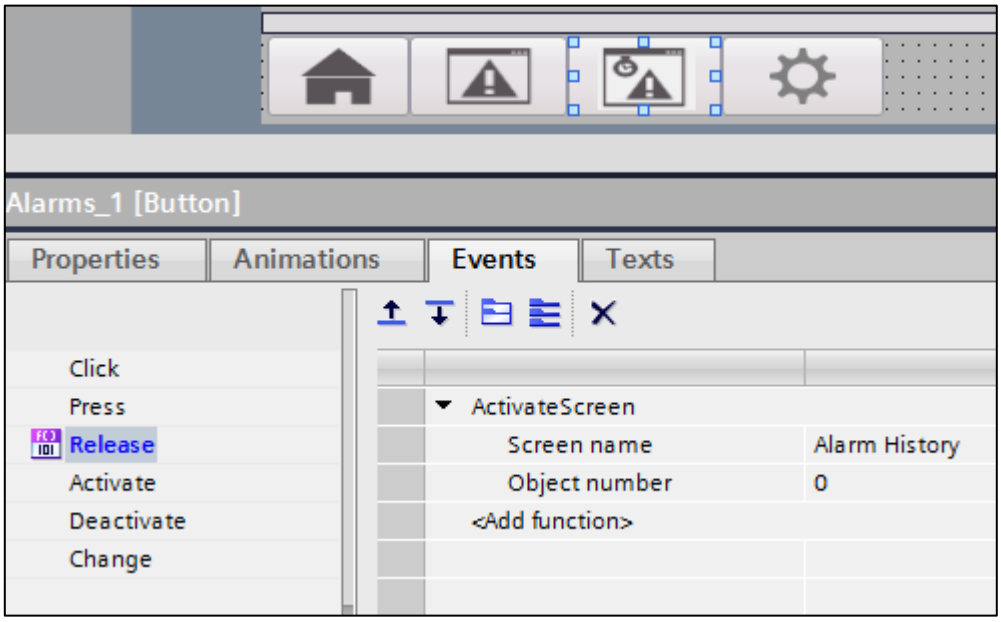


Figure 5. 6 *Activating a screen*

Let us take alarm history icon. This icon event is set to active screen with screen name when it is been release. Same like this every release point of all the icons will active the corresponding screens.

5.1.3 Alarm Screens

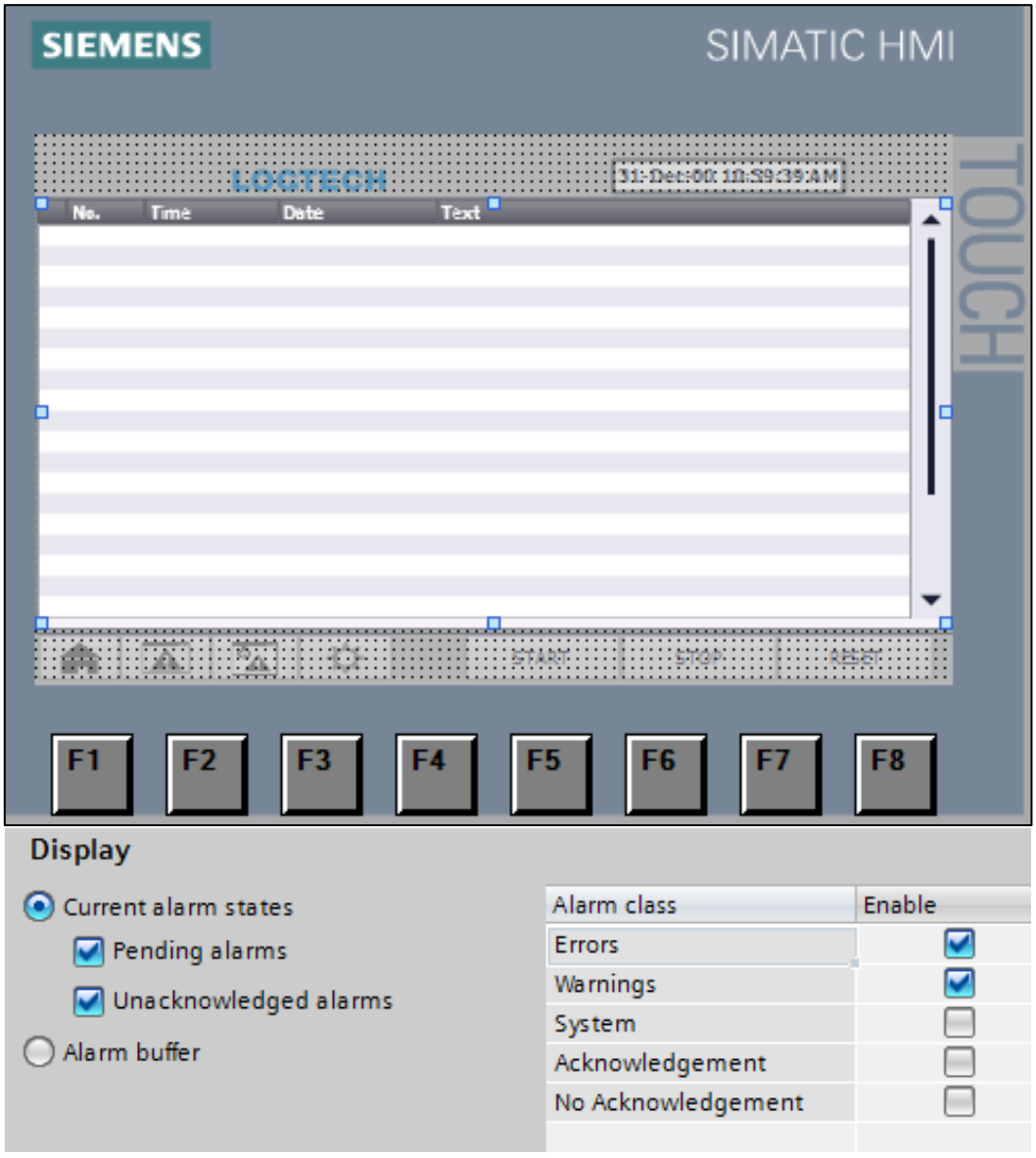


Figure 5. 7 *Alarm screen*

This screen will show the current alarm status which are pending alarms like faults in conveyors and unacknowledged alarms. This screen will show only the errors and warnings in the system.

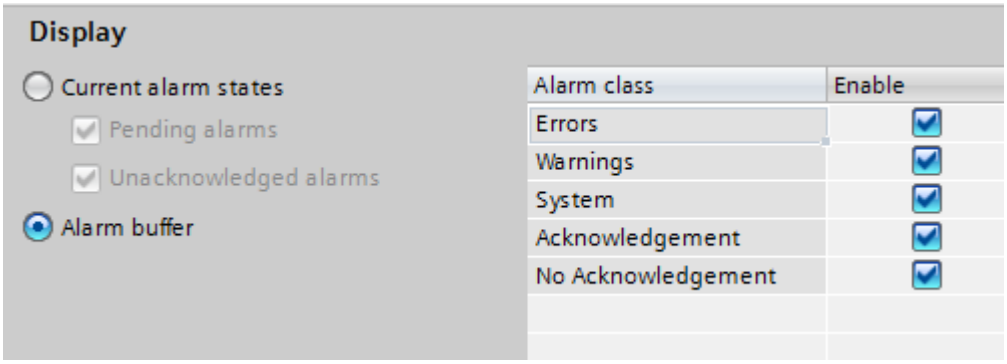


Figure 5. 8 *Alarm history screen*

The alarm history screen will show all the history of the alarm from when it turned ON. It is alarm buffer which will show the errors, warnings, system actions, acknowledgement and non-acknowledgement.

5.1.4 Global Screen

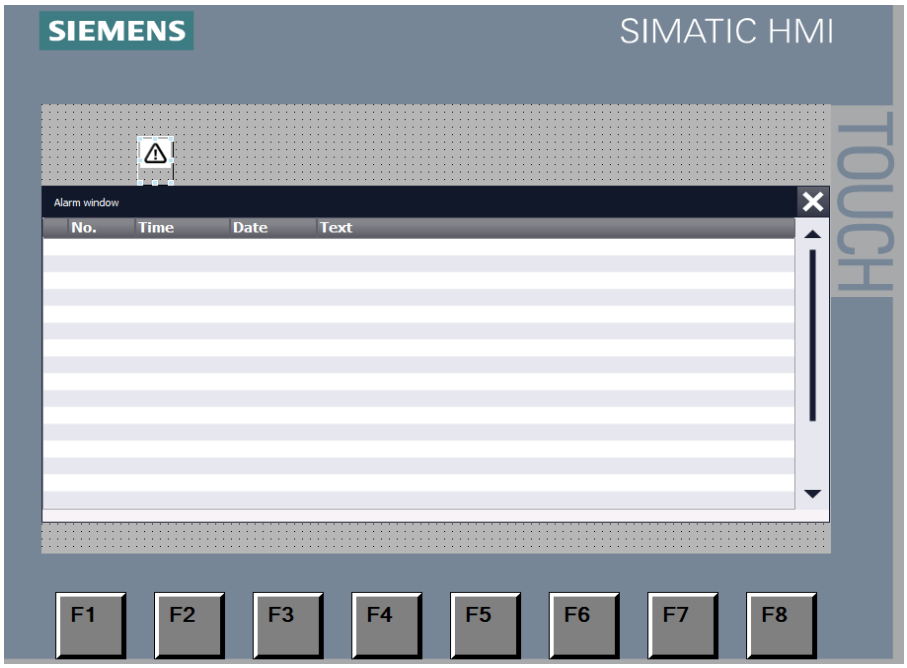


Figure 5. 9 *Global screen*

This screen is same as alarm screen which will pop-up only when there is any error or warning in the system. You can close this screen but the warning mark will remain on the screen until we reset the system.

5.1.5 Fault check Screen

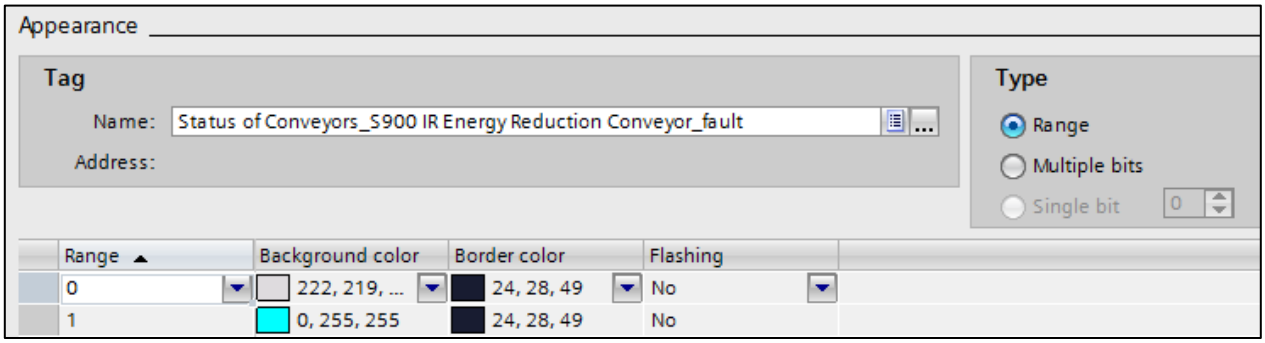


Figure 5. 10 *Fault check screen*

This screen is used to find which conveyor is under fault condition and also it has the similar system design setup like in main screen. If there are any fault in conveyor, the particular conveyor color will change from green/grey to blue. In the figure 5.10, you can see the tag of fault for S900 IR energy reduction conveyor. If this conveyor gets fault, the particular conveyor on the screen will be blue until you reset and restart the system.

5.1.6 Legend Screen

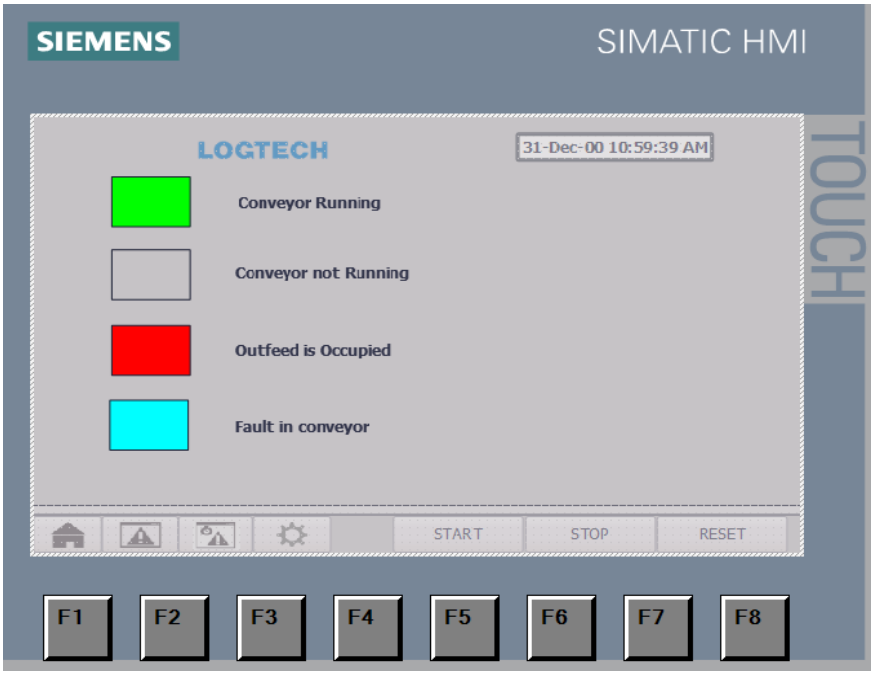


Figure 5. 11 *Legend screen*

This screen will show the legend of all the conveyor status. If the conveyor is running, the object will be in green colour. If the conveyor is not running (resting/energy save), the conveyor object will be in grey colour. If the conveyor is occupied, the conveyor object will be in red colour. If the conveyor has fault condition, the conveyor object will be in blue colour.

5.2 HMI Alarm

ID	Name	Alarm text	Class	Trigger tag	Trigger bit
1	PEC Blockage	PEC Blockage in Infeed Conveyor	Errors	Alarm_Word	0
2	PEC Blockage_1	PEC Blockage in S4400 (Left) Conveyor	Errors	Alarm_Word	1
3	PEC Blockage_2	PEC Blockage in S900 IR energy reduction conveyor	Errors	Alarm_Word	2
4	PEC Blockage_3	PEC Blockage in S4400 (Right)	Errors	Alarm_Word	3
5	PEC Blockage_4	PEC Blockage in S900 FG PP 1 accumulation zone	Errors	Alarm_Word	4
6	PEC Blockage_5	PEC Blockage in S900 FG PP 2 accumulation zone	Errors	Alarm_Word	5
7	PEC Blockage_6	PEC Blockage in S900 IR PP 1 accumulation zone	Errors	Alarm_Word	6
8	PEC Blockage_7	PEC Blockage in S900 IR PP 2 accumulation zone	Errors	Alarm_Word	7
9	Estop	Emergency stop is pressed	Warning	Alarm_Word	8

Table 1 *HMI alarms*

The above table show the HMI Alarm generator of the system. Names are given for every alarm tag. Text which should be shown while alarm is also given. The alarm class will tell the HMI that which kind of alarm has to be generated. Most common class is error and the class will be warning when the emergency stop is pressed. Each alarm will have an ID along with trigger tag and trigger address. Trigger tag is from HMI alarm Tag table of PLC with data type word. The trigger address will be the bit of trigger tag with data type word from HMI tag table in PLC.

5.3 Connection

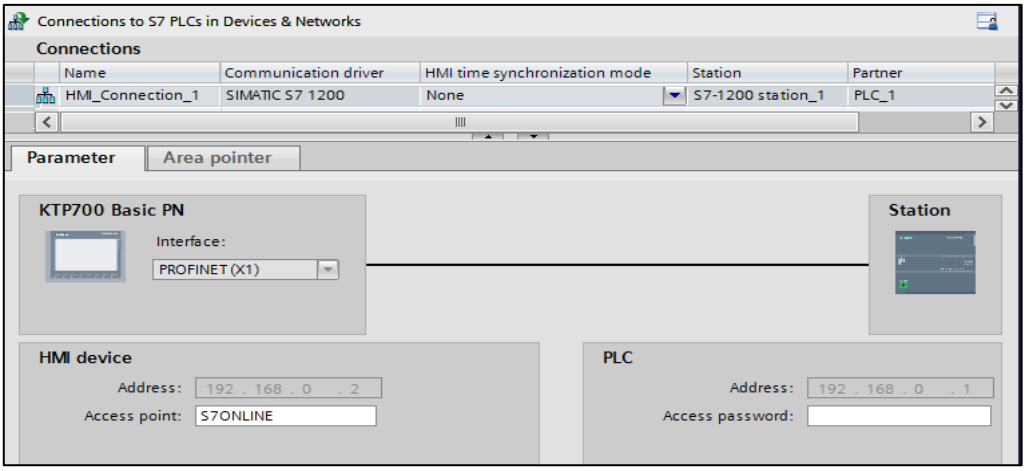


Figure 5.12 Connection to PLC from HMI

The above figure shows the type of connection between the HMI panel and the PLC. Here you can see the address of HMI device and the PLC which are connected together. The access password is from PLC. We can assign access password to PLC. If the password is accessed with PLC, we have to enter the password while downloading or making communication.

6. Verification of designed function on conveyors loop

The objective of this chapter is to validate and testing the working of the system functionality according to the functional description and the specification. The description of the unit is to get the summary of objectives, preconditions and expected results. There are few steps to execute the verification process. For each step there is a column for the actual result.

Verification Activities

There are four different verification activities. They are

i. System functionality
ii. Operations
iii. Error detection
iv. Flow

6.1 System Functionality, Operations & Error Detection

There are five test cases executed in this verification step.

i. Safety
ii. Start/Stop
iii. Normal Flow
iv. Energy saves
v. Die Back

The preconditions required for these verification steps are the equipment should be stopped, error free and empty. The status of the area on the touch panel should be stopped (Conveyors not running).

6.1.1 Safety

Step	Description	Expected result	Actual result
Step 1	Check the pre-condition(s)	The equipment is stopped, error free and empty, the status of the Area on operator panel will be "Stopped" (Grey Colour).	OK
Step 2	Start the subsystem	All conveyors are running, the status of the Area on operator panel will be "Started" (Green Colour).	OK
Step 3	Press the emergency stop button on the cabinet	All conveyors in the Zone are stopped.	OK
Step 4	See previous step	The message 'Emergency stop' is shown on the Operating Panel.	OK
Step 5	Start the subsystem again	Nothing happens	OK
Step 6	Release the emergency stop button	Nothing happens	OK

Step 7	Start the subsystem again	Nothing happens	OK
Step 8	Reset and Start the subsystem again	The messages 'Emergency stop' on the operator panel will disappear and all conveyors will start running again.	OK
Step 9	Repeat step 3-7 for Random emergency stop button in the system	All emergency stops are working properly, including the messages on the OP and the status will be "started" again.	OK

Table 2 *Safety check*

6.1.2 Start/Stop

Step name	Description	Expected result	Actual result
Step 1	Check the pre-condition(s)	The equipment is powered and ready for operation, but not yet started	OK
Step 2	Press Start Button	Check on visual that the general status for the area goes from Stopped via STARTING to Started	OK
Step 3	During STARTING	The start-up light on and the conveyors zone starts	OK
Step 4	See previous	The start-up beeper on the conveyors zone starts	OK
Step 5	See previous	Conveyors NOT running	OK
Step 6	After 05 sec the equipment goes from the collected "Starting" to "Started" status	Conveyors start running	OK
Step 7	See previous	The start-up beeper stops	OK
Step 8	See previous	The start-up light stops	OK

Table 3 *Start/Stop checking*

6.1.3 Normal flow

Step	Description	Expected result	Actual result
Step 1	Check the pre-condition(s)	The equipment is stopped, error free and empty, the status of the Area on Operating Panel will be "Off" (Grey Colour)	OK
Step 2	Start the subsystem	All conveyors are running, the status of the Area on OP will be "On"	OK
Step 3	Keep the tires on the infeed conveyor one by one	The tires going to outfeed properly	OK
Step 4	All tires are transported towards outfeed conveyor without any issues.	All tires coming to outfeed one by one	OK
Step 5	Tire is on outfeed conveyor	Paddle diverter diverts the tires to the accumulation zone.	OK
Step 6	Tires on accumulation zone No tires from infeed	Tires merging on to the S4400 conveyor	OK

Table 4 *Normal flow checking*

6.1.4 Energy saving

Step	Description	Expected result	Actual result
Step 1	Check the pre-condition(s)	The equipment is stopped, error free and empty, the status of the Area on Operating panel will be "Off".	OK
Step 2	Start the subsystem	All conveyors are running, the status of the Area on Operating panel will be "On".	OK
Step 3	Wait for the energy save to start.	Each conveyor goes in Energy Save and stops running.	OK
Step 4	Insert a tire on the most upstream section or infeed section	Each section comes out of the energy-save situation as the tire arrives Upstream and the tire is transported to the most downstream section.	OK
Step 5	Repeat step 1 to 4 for all Area	All Step Passed	OK

Table 5 *Energy saving*

6.1.5 Die back

Step	Description	Expected result	Actual result
Step 1	Check the pre-condition(s)	The equipment is stopped, error free and empty, the status of the Area on Operating panel will be “Stopped”	OK
Step 2	Start the subsystem	All conveyors are running, the status of the Area on OP will be “Started”	OK
Step 3	Create a PEC blockage on one of the conveyors (trigger the PEC until the conveyor stops)	The conveyor stopped and the OP is showing a PEC blockage for the induct conveyor.	OK
Step 4	Insert a tire and let it be transported to the upstream section of the fault conveyor.	The conveyor stops running in Die-Back.	OK
Step 5	Clear the PEC of blocked Conveyor and Press reset	PEC blockage error will disappear from the OP.	OK
Step 6	Press start	The belts are starting to run again.	OK

Table 6 *Die back checking*

6.2 System flow

Step	Description	Expected result	Actual result
Step 1	Check the precondition(s).	The equipment is stopped, error free, and empty.	OK
Step 2	Start the subsystem.	Start-up notification works.	OK
Step 3	See previous step.	Klaxon Horn and Klaxon Yellow giving alert	OK
Step 4	See previous step.	Conveyors in the system start running.	OK
Step 5	Wait for energy save.	Conveyors are halted.	OK
Step 6	Induct tires into the subsystem.	Conveyors recover from energy save successively.	OK
Step 7	See previous step.	Tires are transported downstream towards outfeed	OK
Step 8	See previous step.	Make PEC blockage somewhere in the path of tire	OK
Step 9	See previous step.	The upstream conveyors go into die-back successively.	OK
Step 10	Reset the system	Nothing happens.	OK
Step 11	Restart the system.	The stopped conveyor starts running.	OK
Step 12	See previous step.	The upstream conveyors recover from die-back successively.	OK

Step 13	See previous step.	Tires are transported onto the Outfeed	OK
Step 14	Remove the bags from the Outfeed	Outfeed is empty	OK
Step 15	Stop the subsystem.	The conveyors stop running.	OK
Step 16	Reset and Restart the system	Klaxon Horn and Klaxon Yellow giving alert	OK
Step 17	See previous step.	All the conveyors start running after the alert from klaxon	OK
Step 18	Outfeed is occupied	Paddle diverter diverts the tires to the accumulation zone.	OK
Step 19	No tires from Infeed	Tires merging on to the S4400 conveyor	OK
Step 20	Repeat step 2 to step 19 once again	All steps Pass	OK

Table 7 *System flow checking*

7. Evaluation of the results of work solutions

The idea of conveying tires in a conveyor system has been designed and implemented. The working specification of the system has been analysed as functional analysis of the controlled system with different kinds of functions such as normal flow of the system from infeed to outfeed, accumulation of tires in the accumulation zone if the outfeed is occupied, energy saving mode of the system which means the conveyor is not occupied by tires and photocell blockage.

According to the functional analysis, control system has been designed with devices 10 sensor and 8 motor. As there are a smaller number of inputs and outputs in this project, S7-1200 PLC has been taken as controller without any additional input and output modules. Instead of using IO modules, AS-I communication has been used for connecting inputs and outputs as slave devices where there are only two wires (one for communication and other for power supply).

Now the complete system is programmed by Simatic Step 7 TIA PORTAL using the language ladder builder logic. There are different Function blocks (FB), Functions (FC) and Data blocks (DB) has been used for different functions of the system which means programming must contain everything what are specified in the functional analysis. In order to achieve effective programming, necessary attention has been paid to the structure of the program. Analysis of a complex automation tasks has been divided into smaller tasks or functions based on the structure of the process to be controlled.

For visualization and monitoring, KTP 700 BASIC HMI panel has been used. It contains different screens such as main screen, fault checking screen, alarm screen and alarm history screen which are designed by WINCC from TIA PORTAL. The communication between the PC, PLC and HMI has been done through Ethernet.

Once after the analysing and the designing of the system is done, the system has undergone a acceptance test with checking of the steps of all functions from functional specification. The acceptance test result has been verified.

References:

[1] BERGER, Hans. Automating with SIMATIC. 5th edition. Erlangen, Germany: Public Publishing, 2013, 284 p. ISBN 978-3895783876

[2] BERGER, Hans. Automating with SIMATIC S7-1500: Configuring, Programming and Testing with STEP 7 Professional. Hardcover, 2014. ISBN 978-3895784040. ePDF ISBN 978-3-89578-919-9

[3] Technical documentation of SIMATIC

[4] Prafulla Mahure. Functional Specification of Sarajevo Airport. Refernece Vandelande 05279-420-00001-EN-C. Publishing 2nd August 2016

[5] Siemens Industrial Control, AS-i Master CM 1243-2 and AS-i Data Decoupling Unit DCM 1271 for SIMATIC S7-1200. Edition 04/2013. Reference: A5E02655230010A/RS-AA/003. Order number: 3ZX1012-0RK71-1AC1

[6] Operating Instruction od SEW EURODRIVE. Movimat with AS_Inteface. Edition 11/2009. Reference number: 16817613/EN

[7] SIEMENS SIMATIC S7-1200 Programmabe controller Sytem manual. Edition: 04/2012. Reference number: A5E02486680-06

[8] SIEMENS. Configuration Messages and alarms in WinCC (TIA PORTAL) – Extenstion with S7-1200/S7-1500. Edition 05/2018. Entry ID: 62121503

[9] Intralox Conveyor Belting Enginnering Manual

[10] W27-3P3402S17 SICK sensor Online data sheet